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MEMOIRS OF THE GEOLOGICAL SURVEY.

# SUMMARY OF PROGRESS

OF THE

# GEOLOGICAL SURVEY

OF THE

# UNITED KINGDOM

AND

# MUSEUM OF PRACTICAL GEOLOGY

FOR

# 1901.

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# CONTENTS.


PAGE

INTRODUCTION BY THE DIRECTOR ... ... ... ... ... .. 1

I. ENGLAND AND WALES.

I. FIELD-WORK ... ... ... ... ... ... ... ... 4

1. Midland District ... ... ... ... ... ... 5

2. Southern District ... ... ... ... ... ... ... 16

3. South Wales District ... ... ... ... ... .. 34

4. Examination of new Railways and other Sections ... 53

Notes on a new Railway in course of construction between Axminster and Lyme Regis ... ... ... ... 53

Further notes on the cuttings along the South Wales Direct Railway ... ... ... ... .. ... ... 59

Report on the Examination of the Sections at the Reservoirs, and along the course of the Aqueduct of the Birmingham Corporation Waterworks, Rhayader to Frankley ... ... ... ... ... ... ... 60

Notes on the Goole and Marshland Light Railway ... 64

II. PETROGRAPHICAL WORK ... ... ... ... ... ... 65

Rocks of the Southern Highlands ... ... ... ... 65

III. CHEMICAL WORK ... ... ... ... ... ... ... 71

Analytical methods in use in connection with the examination of South Wales Coals ... ... ... ... ... 73

Rottenstone from South Wales ... ... ... ... 80

Weathering of Magnesian Limestone ... ... ... 83

Minerals from Skye and Ross-shire ... ... .. .. 86

Tertiary Igneous Rocks from Skye ... ... ... ... 87

Rock from Newlyn, Cornwall ... ... ... ... ... 88

Pseudogaylussite from the Clyde ... ... ... ... 89

IV. PALÆONTOLOGICAL WORK ... ... ... ... ... ... 91

List of Specimens in Museum recently figured ... ... 93

V. MUSEUM OF PRACTICAL GEOLOGY ... ... ... ... ... 93

VI. MAPS, SECTIONS, AND MEMOIRS, PREPARED AND PUBLISHED 94

II. SCOTLAND.

I. FIELD-WORK ... ... ... ... ... .. ... ... 95

1. Northern District ... .. .. ... ... ... 95

2. West Highland District ... .. .. ... ... 118

3. East Highland District ... ... ... ... ... .. 157

II. PALÆONTOLOGICAL WORK .. ... ... .. .. ... 177

Notes on Carboniferous Plants collected in Berwickshire 179

A new species of *Gyracanthus* ... ... ... ... ... 181

List of Specimens in the Survey collection recently figured 182



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## CONTENTS—*Continued.*


PAGE

II. SCOTLAND—*Continued.*

III. Museum Work ... ... ... ... ... ... ... ... 182
IV. Maps, etc., Published ... ... ... ... ... ... 183

III. IRELAND.

I. Field-Work ... ... ... ... ... ... ... ... 183
Dublin District ... ... ... ... ... ... ... 183

II. Maps Published ... ... ... ... ... ... ... 199

APPENDIX : A. Catalogue of Types and Figured Specimens of British Fossil Phyllocarida preserved in the Museum of Practical Geology, London 200

„ B. Catalogue of Types and Figured Specimens of British Palæozoic Echinodermata preserved in the Museum of Practical Geology, London ... ... ... ... ... ... ... 204

Index ... ... ... ... ... ... ... ... ... ... 212


## ILLUSTRATIONS.


Fig. 1. Section south-west of Shools Farm, near Axminster . 54
Figs. 2 and 3. Railway cutting north-east of Great Trill, near Axminster 55
„ 4 and 5. Sections near South Ground, Linhay, south of Axminster 56
Fig. 6. Section east of Combe Pyne Station ... ... ... ... 58
„ 7. Cutting west of Bradfield Farm, Hullavington ... ... 60


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# SUMMARY OF PROGRESS

OF THE

# GEOLOGICAL SURVEY

AND

# MUSEUM

FOR 1901.

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## *INTRODUCTION.*

The field work for the year 1901 was concentrated in definite areas and was placed under the charge of District Geologists. In view of this method of carrying on the work it has been thought desirable to make the annual record of progress reflect the organisation of the Survey. The chronological arrangement which has been adopted in previous *Summaries* has therefore been abandoned in favour of a geographical arrangement. Mr. Teall.

The work in England and Wales was under the general charge of Mr. H. B. Woodward, F.R.S., and was carried on in three districts, which are referred to as the Midland district, the Southern district and the South Wales district.

In Scotland the work was superintended by Dr. John Horne, F.R.S., and was of necessity somewhat more scattered. In the following report the results are grouped also under three districts: the West Highland district, including Skye; the Northern district; and the East Highland district.

The work in Ireland, which is limited to a re-survey of the drift-covered areas, was in charge of Mr. G. W. Lamplugh and was carried on in the neighbourhood of Dublin.

A few of the more important results will now be briefly indicated.

In the Midland district the detailed mapping on the six-inch scale has led to some modification of the earlier maps. The so-called Permian outlier west of Rushton has been proved to belong to the Lower Carboniferous series. The Triassic area which forms the greater portion of Sheet 110 is for the most part covered by glacial and fluvio-glacial deposits. Some interesting details as to the nature, distribution and probable mode of origin of these deposits will be found in the following pages.

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Mr. Teall. In the west of England the process of subdividing the great killas-formation of De la Beche has been continued, and a new division—the Hayle Sandstone—has been recognised. There is every reason to hope that as this important work proceeds the structure of the district will be made out and the true relations of the Devonian to the pre-Devonian rocks ascertained.

A considerable mass of granite, later in date than the main mass, has been found in the Land's End district, thus proving that the granitic area is not so simple in structure as is represented in the earlier maps. Special attention has been paid to the metamorphism produced by the granite, not only on account of its scientific interest, but also because the more important mineral veins occur in the metamorphic zone. Some isolated metamorphic areas, which indicate the proximity of granite to the present surface in districts where no granite is visible, have been met with. The work of recording the mining information has been delayed pending the appointment of an officer whose duty it will be to devote himself especially to this object. The appointment has now been made and the work will be proceeded with.

In the Devonian and Carboniferous areas of the west of England additional evidence has been obtained of an important unconformity between the Middle Culm or Wearde beds and the Devonian. The Lower Devonian succession has been worked out in a more satisfactory manner than heretofore.

The progress of the work of mapping the South Wales coal-field has necessitated the examination of the Lower Palæozoic rocks which come within the northern border of Sheet 230. The Ordovician and Silurian rocks which occur within the sheet have been examined, but no natural undisturbed junction has been met with. Evidence of faulting, probably accompanied by over-thrusting, has been found all along the line, and the dominant movements have been connected up with the disturbances of Cribarth and the Vale of Neath to which reference has been made in previous summaries.

Inliers of Silurian rocks, hitherto unsuspected, have been found in Gower, thus proving a great but, probably, local diminution in the thickness of the Old Red Sandstone. No definite separation of Upper and Lower Old Red Sandstone has yet been found possible. The sequence of red beds appears to be conformable throughout; but, on the other hand, there are signs of an unconformity between the Old Red Sandstone and the Silurian rocks.

The deep trough of Coal Measures extending from Swansea to Llanelly has been further examined and found to contain some of the highest measures of the coal-field. Two outliers of Trias have been proved to occur in Gower.

The transportation of glacial drift which has taken place in a general south-westerly direction in the districts previously examined, has had a southerly impulse given to it across the northern and western portion of the Carboniferous area, from which the presence of a great body of ice in Central Wales may be inferred.

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In the northern district of Scotland, work has been carried on in Ross-shire and Inverness-shire, extending eastwards from Loch Hourn and Loch Ailsh. Much additional information has been obtained as to the crystalline schists and the associated igneous rocks. The Glenelg plutonic complex has been found to consist of acid, intermediate, basic and ultra-basic rocks which have been intruded into the Moine-schists. The more acid members of the series have been sheared and granulitised in certain places by later movements, and dykes of quartz-felsite, porphyrite and mica-trap traverse the complex. Mr. Teall.

In the Alness district of Ross-shire, a bluish grey mica-schist belonging to the Moine series has been traced into a banded hornfels which forms a contact zone round augen-gneiss. From this it has been inferred that the contact metamorphism was anterior to the movement which produced the foliation in the Moine series. Lenticular sills of hornblendite and two small exposures of the rare and interesting rock known as scyelite have been observed in the same district.

In the West-Highland area, dykes of a dioritic rock precisely resembling the malchites of the Odenwald, have been met with near the head of Loch Eil. They traverse muscovite-bioitite-gneiss, amphibolite and pegmatites, but are also cut by thin strings of pegmatite.

In the central district of Scotland, the examination of an area between Pitlochry and Blair Athol has brought to light important evidence bearing on the sequence of the Highland-schists in that area. The graphite schist, which is in many places separated from a mass of black schist by folded quartzite, has been traced continuously round the folds into the black schist, and the identity of the two in that area has, therefore, been established. The quartzite appears to be the highest member of the series, and there is some evidence of an unconformity at its base. Interesting evidence bearing on the age of the newer granite has been obtained. In the Alness district of Ross-shire the basal conglomerate of the Old Red Sandstone contains fragments of these granites, whereas in the region north of Clachlet in Argyllshire, the volcanic series, which is presumably of Lower Old Red Sandstone age, has been pierced by granite. It is not improbable that many of the newer granite masses belong to some portion of the Old Red Sandstone period which is known to have been a period of granitic intrusions in other portions of the British Isles.

The work in the Skye district has led to the recognition of Cretaceous rocks in Soay Sound and Scalpay. The zone of *Pecten asper* has been definitely identified in the latter island, and evidence of the great Upper Cretaceous transgression has thus been found where it had not been hitherto suspected.

An interesting series of composite dykes of Tertiary age has been found in the Lorne Plateau. Some of these have been filled at three successive periods; the earliest intrusion being olivine-dolerite and the latest quartz-felsite. Along one of these composite dykes a series of neck-shaped masses composed of agglomerates and lavas has been mapped.



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Mr. Teall.

The detailed mapping of the drifts in Ireland was commenced in the Dublin area. A large portion of this area is deeply covered with drift which, therefore, has a much greater influence on the nature of the surface than the solid geology.

The general composition and distribution of the drifts, the manner in which they have modified the pre-glacial topography in the lower portion of the area, and have, in turn, been modified by this topography in the higher ground, as well as their influence in determining the character of the soil, are briefly summarised in the following pages.

Among the points of interest arising out of last season's work are two which deserve special mention. The esker-like ridge, south of the Liffey, has been found at one point to rest on a water-worn floor of Carboniferous Limestone. At the same locality the gravels of the ridge can be seen to pass laterally into gravelly clay, full of scratched stones, resting on a striated rock surface. These facts strongly support the widely accepted view that ridges of this type are the casts of sub-glacial water-channels.

The examination of the northern slopes of the Dublin Mountains, included within Sheet 112, has led to the conclusion that the short, deep, water-cut gorges, which occur as notches on many of the projecting spurs, like similar gorges recently described in other regions, have been excavated by powerful streams, either draining directly across ice or representing the overflow from lakes held in between the hills on the one side and the margin of the ice-sheet on the other.

# I.—ENGLAND AND WALES.

## I.—FIELD-WORK.

Mr. Woodward.

The ground to be surveyed was arranged in three areas under the District Geologists as follows:—

1. Midland district under Mr. C. Fox-Strangways.
2. Southern district under Mr. Clement Reid, F.R.S.
3. South Wales district under Mr. A. Strahan.

In the Midland area the surveys of Sheet 110 (Macclesfield) and of 141 (Derby and Loughborough), together with that of the Cheadle coal-field in Sheet 124, have been finished. The Memoir in Explanation of Sheet 156 (Leicester) has been completed, while those in explanation of Sheets 110 and 141 and district memoirs on the North Staffordshire coal-field, including that of Cheadle, and on the Leicestershire coal-field are in preparation.

In the Southern area, Sheet 351 (Penzance) has been completed with the exception of the mining information. The Memoir in Explanation of Sheet 314 (Ringwood) was finished, and this, as well as memoirs dealing with the geology of Exeter and Southampton, would have been published, but that questions

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concerning a uniform price for memoirs have caused delay. The Memoirs on Sheets 298 (Salisbury), 317 (Chichester and Midhurst), 350 (Torquay), and 355 and 356 (Kingsbridge and Start Point) are in hand. Mr. Woodward.

In the South Wales area the survey of Sheet 247 (Swansea) has been completed, but some colliery information has yet to be obtained. The Memoir in Explanation of Sheet 263 (Cardiff) was finished, and other memoirs on Sheets 231 (Merthyr Tydvil), 248 (Pontypridd), and 262 (Bridgend) are in hand.

Proofs of the general memoir on the *Cretaceous Rocks of Britain*, vol. ii., by Mr. Jukes-Browne, and of that on the *Geology of the Isle of Man*, by Mr. Lamplugh, are still in hand. A memoir on the *Water Supply of Berkshire* has been completed, and we are indebted to Mr. H. W. Monckton for editing the MSS. left by the late Mr. J. H. Blake on the geology of the country around Reading in explanation of Sheet 268. The publications during the year are noted on page 94.

In addition to the ordinary field-work, special examinations have been made of new railway cuttings; those from Axminster to Lyme Regis, and from Alderton to Wootton Bassett (on the South Wales Direct Railway) were noted by myself, and the sections exposed by the Goole and Marshland Railway were recorded by Mr. Gibson.

Through the courtesy of Mr. James Mansergh, F.R.S., then President of the Institution of Civil Engineers, Mr. T. C. Cantrill had the opportunity of examining the sections along the course of the aqueduct of the Birmingham Corporation Waterworks from Rhayader to Frankley; and by kind permission of Mr. A. McDonald Cobban, Mr. Gibson was enabled to examine a series of cores from a deep boring at Scunthorpe in Lincolnshire.

## 1. Midland District.—Cheshire, Staffordshire, and Derbyshire.

Mr. C. Fox-Strangways, District Geologist.
Mr. W. Gibson
Mr. T. I. Pocock
Mr. C. B. Wedd
Mr. J. Allen Howe
} Geologists.

### Lower Carboniferous Rocks (Cheshire and Staffordshire).

These rocks occupy the eastern side of Sheet 110. They are arranged in a series of synclinal and anticlinal folds running in a more or less northerly direction. The northern part of this region has been mapped by Mr. Pocock, and was described in the last *Summary of Progress*; the southern portion has been mainly surveyed by Mr. Wedd, with the exception of the ground north of Rushton Spencer, which has been done by Mr. Howe. Mr. Fox-Strangways.

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Mr. Wedd. The Lower Carboniferous shales and sandstones in this area rise into a well-marked anticline running N. and S. by Lask Edge, High Bent, and Brown Edge. The structure is well shown by the change of dip in the shales and grits in Dingle Brook, which flows round the north end of the ridge; and in the cloughs between Cloud Hill and Rushton, where the anticline appears to be pitching down or dying out northwards. This fold is succeeded on the east by a shallow syncline running approximately N.N.W. on the west side of Rudyard Reservoir, as is well shown by the ridges of the Third and Fourth Grits. East of the reservoir another syncline runs in the same direction between Rudyard and Heaton, the outcropping edges of the Fourth Grit illustrating the structure. Both these synclines appear to be dying out northwards. Between them the relatively narrow valley of the Rudyard Reservoir may be assumed to be occupied by an anticline, perhaps in part cut out by a fault running along the valley. East of the Rudyard-Heaton syncline another anticline running W. of N. brings up the so-called "Yoredale Sandstones" again along the edge of the map.

The folding of the hard Millstone Grits intercalated with soft shales is accompanied by a certain amount of local faulting. A fault with northerly downthrow runs E.N.E. across the Horton syncline through Raecliff Wood, where it displaces the Third Grit; it also probably throws the Third against the Fourth Grit on the east side of the reservoir. A short distance further north there is a similar fault with the same downthrow. Just north of Hollins an E. and W. fault with northerly downthrow crosses the anticline of Lask Edge and is continued on into the Biddulph Valley. The purple grit of Rushton appears to be cut off on the south and thrown against shales by a N.W. fault passing south of the Crown Inn. A N.W. fault passing under Wellbeach House west of Rushton Station seems to throw down the Bunter on the east against Lower Carboniferous, and the eastern boundary of the Bunter is considered by Mr. Wedd to be probably also faulted.

On the top and along the flanks of the anticlinal ridge extending by Lask Edge, High Bent, and Brown Edge, red, purple, and white sandstones are exposed, which are upwards of 20 feet in thickness. These beds are indicated on the old survey map as "Yoredale Sandstones." The same series of sandstones and shales comes to the surface east of the Rudyard syncline. In one of the highest sandstones in this series near Dingle Brook, on the west side of the western anticline, there is a two-inch band of hard grit crowded with casts of small lamellibranchs (*Posidoniella*?). This band is separated by thin black shales from a higher bed of grit with plant remains. Above this there is a thick series of black shales with hard sandstones and layers of calcareous bullions containing *Goniatites* in abundance; these are well seen in Dingle Brook; and in Lee Wood, Rushton. The shales are succeeded by several grits of the Millstone Grit series, which are more numerous and thicker than in the Biddulph valley. Commencing at the north the lowest grit is seen at Heaton and Fairboroughs. It consists of lavender or grey, flaggy, micaceous

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grit with intercalated beds of purple shale, resting on very massive, hard, grey grit, with occasional pebbles. This grit appears to be the so-called "Permian" of the old survey. Though similar in colour to the lavender sandstones of the Keele series of the Upper Coal measures, it is a sharper, harder, and more quartzose grit, weathering to red sand rather than to crimson marl. Though it clearly overlies black shale, Mr. Wedd has not been able to find any section showing its relation to higher beds; but at the same time it conforms markedly in strike and dip to the folding of the Lower Carboniferous shales. The grit, shown on the old map as a small isolated patch of "Permian," some little distance west of Rushton, is clearly a ridge of grit overlying black shales and dipping N.W. in strict unison with the folding of the Lower Carboniferous of the locality, to which it clearly belongs. The general strike of the beds about Lee and Rushton also shows that these so-called Permian beds belong to the Lower Carboniferous series. Near the Inn, a red and purple grit with white blotches, shown on the old map as Bunter, is on the same strike as these beds, and undoubtedly of the same age. Mr. Wedd.

The shallow syncline of Horton, which appears to be diminishing or dying out northwards, will in its northerly continuation occupy the ground between the main anticline of Rushton and the syncline of Heaton, against which latter it is probably faulted, the intervening anticline being mainly cut out. Consequently it may be expected that the beds here will be wrinkled into but slight folds, or will be nearly flat, so that a bed occurring at the surface would remain at or close to the surface for a considerable distance.

A short distance S.S.E. of Rushton Church, lavender grit, similar to that described above, is seen, and it is probably identical with the lowest grit of Heaton (the Fifth Grit). Above this the Fourth Grit bends round with the syncline, and is exposed at Heaton. It is a thick, massive, pink and white, rather coarse-grained grit with seams of small pebbles. This grit re-appears on the west side of the Rudyard Reservoir below the Third Grit in Raecliff Wood, and is repeated by a fault. It bends round in another syncline, and runs south of Horton, where it forms a strong ridge below the Third Grit. Some distance further N.W., below Cloud Hill, two or three thin beds of grit which are close together occupy the same relative position below the Third Grit. These are doubtless the attenuated representatives of the Fourth Grit of Heaton and Horton. On the west side of the Biddulph valley no trace of this grit is seen, so it has doubtless died out.

The highest grit seen in this area is a massive, compact, rather coarse-grained false-bedded red and white grit, with seams of pebbles. It rises in a ridge above the Fourth Grit, and runs from Rudyard Reservoir N.N.E., passing east of Hunt House. On the west side of the reservoir the same grit bends round in a syncline and occupies the high ground of Harpers Gate and Grindlestone Edge.

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TRIASSIC (STAFFORDSHIRE AND CHESHIRE).

Mr. Wedd and Mr. Howe.

*Bunter.*—A small patch of Bunter comes into the ground under consideration to the north of Rushton, but the area occupied by the rock is not so extensive as indicated on the old survey map. Mr Wedd finds that it consists of the usual red and mottled sandstone with more or less abundant pebbles. It seems to be brought against the Lower Carboniferous on the west by a fault running N.W. under Welbeach House. It is probably bounded on its eastern side also by a fault. In the river banks above Hug Bridge there is an interesting exposure of these beds which has been mapped by Mr Howe. The upper 20 or 30 feet of these, well seen in Red Pool, consists of soft red sandstone with small pebbles and lenticular patches of red marl of varying size; they pass down gradually into a more marly group, shown in the river bank 200 yards east of Hug Bridge. These red marls, which are described in the memoir on *The Geology of the Country round Stockport, Macclesfield, Congleton and Leek*, p. 36, as of Permian age, are now considered to be the lowermost of the visible Bunter beds; they contain numerous bands and lenticular patches of bleached sandy marl. It is the similarity of these markings to those of the Permian of Manchester that seems to have led previous observers to place these beds in the Permian.

*Keuper.*—In the western part of the map Mr Gibson has found that the Keuper marl is only exposed on the banks of the River Dane, and in the stream near Belchow House. Messrs. Wedd and Howe also report exposures of Keuper marl along the Wheelock and Weaver with the tributaries the Croco and Wade Brook, and in the deep cloughs north of Congleton. It consists principally of red marl with thin beds of gypsum, and a few thin red and white flags at intervals. The beds are much disturbed and sometimes sharply folded, but there is a general westerly dip.

TRIASSIC AND LIASSIC (DERBYSHIRE).

Mr. Fox-Strangways.

The revision of the country to the south of Derby in the northern part of the one-inch Map 141 has shown that the only solid strata that come to the surface are the Keuper marl, and two small outliers of Lias and Rhætic beds. The Keuper marl forms rising ground between the Trent and Derwent, as well as to the north of the latter river, and to the east of the Soar. There is, however, very little of interest to note in this formation. It consists of the usual red marls; but in the neighbourhood of Derby it becomes more sandy, although there are no special beds of sandstone that can be separated out, as has been done on the south side of the Trent. Just beyond the northern edge of the map these sandstone beds appear to become rather stronger, and it is probable that they will be able to be traced in that country. At Chellaston, and to the east of the Soar at Thrumpton, Kingston, and Gotham, the Keuper marl contains an important bed of gypsum, which is worked at these places. It varies in thickness,

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the average being about 6 feet, but occasionally it is said to be much thicker. Although the gypsum usually dissolves when near the surface, its outcrop can be traced with considerable accuracy for some miles. Mr. Fox-Strangways.

In the neighbourhood of Gotham there are two conspicuous outliers of Lower Lias and Rhætic beds, which constitute the extreme N.W. outcrop of these beds in this district. The dark Rhætic shales have been seen at a few places; and, from the outcrop always occurring on a steep escarpment, is not difficult to trace.

The lowest beds of the Lias form a nearly level surface on the summit of these hills, and the limestone has been quarried at several places, but the beds are not thick enough to be of much commercial value.

## PLEISTOCENE (DERBYSHIRE).

In the south-eastern portion of the county there is very little true glacial drift; but the post-glacial beds are very extensive, and of considerable interest. The separation between the two is not easy to define, as will be seen presently.

The principal deposit of Boulder-clay occurs at Chellaston, which is situated at the end of the ridge separating the valley of the Trent from that of the Derwent. It occupies eroded hollows in the marl, and consists of two separate deposits, the included fragments being derived from the north and west in the lower clay, and from the east in the upper. The other patches of Boulder-clay are of no great thickness, and occur along the ridge between Mickleover and Derby; in the low ground south of Derby, and along the rising ground north of Barrow-upon-Trent. A good deal of coarse gravel occurs along the ridge by Mickleover, Littleover, and Derby, but it is not easy to separate it from the general mass of drift. There is also a scattering of pebbles over nearly the whole of the ground; the importance of which, in the absence of sections, it is difficult to estimate. The most important beds are, however, the post-glacial deposits of the Trent and Derwent valleys, which have been ably described by Mr Deeley.* Although Mr Deeley's sub-divisions are in the main correct, it is not easy to follow his correlation of the different beds. There are gravels of three or more periods in these valleys, which more or less resemble ordinary river gravels, and Mr. Fox-Strangways cannot find any evidence that these are "interglacial." The highest gravels may be of late glacial age, having been laid down when glacial conditions still existed in the neighbourhood, but there is no true Boulder-clay over them. They, in fact, form a connecting link between glacial and post-glacial times. The highest of these terraces is about 50 feet or more above the present river flat; and although generally forming a fairly level plain they, in some cases, gradually rise on the inner side quite another 50 feet or more. It is here that they become difficult to separate from glacial beds, and we propose therefore to call them "high level valley gravel."

* *Quart. Journ. Geol. Soc.*, vols. xlii., p. 437, and lii., p. 497.

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Mr. Fox-Strangways.

The principal terrace is from 15 to 20 feet above the modern alluvium, against which it usually terminates in a well-defined bank. On the south side of the Derwent this terrace has a breadth of a mile and a half, and at Allenton contains the remains of *Hippopotamus.** Below this are other terraces, which merge into the alluvium of the present rivers; so that, although they end off in a steep bank on the higher side, they usually tail off down stream, and cannot be separated from each other.

There are two interesting deposits of lacustrine clay occupying old hollows in the Keuper marl; one of these, Sinfin Moor, has an area of about 2 square miles†; and the other, Gotham Moor, is probably double this size, but the mapping of the latter is not yet completed. The deposit of this latter place is a white marl with much vegetable matter, but the specimens yet obtained are too decayed to be determinable. In the Erewash Valley close to Toton Sidings a stiff marly clay with shells occurs beneath the present alluvium of the stream, in which Mr. Clement Reid notes the following species—

*Limnæa (peregra ?).*
*Valvata piscinalis.*
*Bithynia tentaculata.*
Chrysalis cases (several species).
*Daphnia* (winter eggs).
Lycopod (spores).
*Scirpus lacustris.*

The Trent alluvium shows a great number of old river courses, one of which is of historical interest as being mentioned by Shakespere‡; it is close to the village of Repton, and has a length of about 2 miles.

## GLACIAL (CHESHIRE).

Mr. Gibson.

The drift occurring in this district consists of two main types —the older Boulder-clay or true till; and the later fluvio-glacial deposits with which we have principally to deal. As the former of these has been seen at very few places there is little to be said about it. The fluvio-glacial deposits however cover the greater part of the district; and, starting from a level plain of about 150 feet at Crewe and Middlewich, gradually rise about Congleton and Macclesfield, till in the hills beyond they attain an altitude of about 800 feet.

The western part of the district is best described under two divisions—the general flat of Crewe, Sandbach and the country to the north; and the ground bordering the Dane river, which intersects this plain. Mr. Gibson finds that sections are not numerous except in and around the Dane valley; where, however, the sands and clays appear to be of a different origin from those around Sandbach.

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* H.H. Arnold Bemrose. *loc. cit.* p. 497.
† Mr. Deeley gives a section of the Sinfin Moor deposits. *loc. cit.* p. 502.
‡ *Henry IV.*, Pt. I., Act iii., Sc. 1.

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Mr. Gibson.

The sands and clays of the general plain are apparently unstratified, and of very varying thickness, being only a few feet thick at Wheelock and Betchton, and over 70 feet around Sandbach. The relation between the sand and clay is not determinable, but as a rule clay overlies an irregular surface of sand, which is itself deposited on an irregular floor of Keuper marl. A few glaciated boulders occur in the clay, but the sands are remarkably free of pebbles of any kind. The sands attain their maximum thickness at Sandbach, but thin out rapidly on approaching the Weaver valley to the west, or the Dane valley to the north.

Around Crewe, and for some distance to the west, there is a finely laminated clay, but its relation to the beds further north is uncertain. A boring in the town proved 30 feet of sand overlying 150 feet of clay.

In the valley of the Dane south of Cranage Hall, and at the Viaduct, beds of Boulder-clay are seen which are the oldest glacial deposits of the district. They are about 30 feet thick, and consist of stiff, brown clay full of striated stones with numerous fragments of *Turritella* and *Cardium edule*. This till is overlaid by a fine, brown, laminated clay which is seen in a brickpit south of Cotton Hall, and appears occasionally to occupy the lower part of the banks of the Dane and other streams. It is overlaid by a light-coloured stratified sand, which spreads out over the surface of the surrounding plain.

Mr. Wedd and Mr. Howe.

Nearer Congleton Mr. Wedd observes that the drift seen in the cliff-sections of the Dane is only a few feet thick, but away from the Dane the thickness is considerably greater. A well on the west side of Eaton Park showed a thickness of 63 feet without reaching the Keuper marl. It is of the usual character; but, besides the common type of current-bedded sand and gravel, sometimes containing shell fragments, there is a somewhat different deposit of yellow sand occupying flat-bottomed valleys (in many cases flanked by normal moundy drift) or level plains. This sand is entirely free from gravel, and probably has a different origin from that of the ordinary glacial drift. It seems to have been reconstructed out of drift material during the earliest stages of the Dane drainage system. These flat sands are sometimes seen to rest upon Boulder-clay. In the ordinary moundy glacial drift the boulders are much the same as those described in previous reports, Ennerdale granophyre, Eskdale granite, and various types of the Lake District Volcanic series being abundant. Small boulders of crinoidal Carboniferous Limestone are sometimes found, and grey flints occur sparingly.

In the country north of the Dane Mr. Howe finds the same general succession. The greater part of the area is occupied, at the surface, by stiff, brownish, finely laminated clay; the remaining portion is covered by clean yellow sand. About Peover Superior, Allostock, and north of Goostrey a sheet of sand rests persistently on the laminated clay; but about Nether Peover the relation of the two deposits becomes obscure. Along the Crow Brook this order is reversed, and a clay reposes on sand. Some

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Mr. Wedd and Mr. Howe.

of the ground mapped as clay consists of good stiff clay, which is so full of small lenticles of clean sand, that after cultivation the soil assumes quite a sandy aspect. Occasionally these lenticles swell out into rounded hills of sand.

The relation of the Dane valley deposits to those of the rest of the plain has not been made out, from the fact that they are never seen together in any one section, and their outcrop is always a feather edge. It is probable however, that they are more recent, and fill in an old line of drainage across the plain.

As we approach the hills the drift becomes much thinner and very irregular in its distribution. Mr. Wedd finds that the Millstone Grit ridges and the porous Bunter sandstone are generally bare of drift. Both clay and sand lie on the high ground within the syncline of the Fourth Grit south of Heaton, but it is doubtful whether there is any in a similar position within the syncline of the Third Grit of Harper's Gate and Grindlestone Edge. The drift of this tract is on the whole similar in composition to that of the plain, and consists of red and brown stony and often sandy clay, with patches of sand and gravel. Amongst the boulders there is naturally a greater proportion of local Carboniferous material, principally fragments of the Millstone Grit and lower sandstones. Boulders of Carboniferous Limestone also occur, and, in the neighbourhood of Heaton and Rudyard, Bunter pebbles are abundant. No shell fragments have been found in this tract, though they occur in the Biddulph valley. The drift, filling the valleys between the anticlinal and synclinal grit ridges, is for the most part flat or gently sloping with few definite mounds; but at Rushton, about the mouth of the Rudyard valley, it is moundy.

Mr. Pocock.

In the district west of Macclesfield Mr. Pocock observes that the drift, which occurs at the surface over the greater part of the low country, belongs to a stage of the glacial period when the *mer de glace* had retreated from the Pennine Hills, and wide sheets of water stretched along the plain at their foot. The rivers Bollin and Dean, emerging from the upland valleys, coalesced on the lowland, and deposited their silts and gravels in terraces along the flanks of the hills. Some account of one of these terraces, which occurs at about the 500-feet contour, was given in last year's report, where it was stated that the shoreline was situated near a ridge of the Triassic formation which abuts against the Carboniferous rocks three miles south of Macclesfield. But there are indications that the water had previously stood at a higher level, and overflowed the Triassic ridge into the basin of the Dane. A thick deposit of chocolate-coloured brick-clay is found at a level of about 570 feet on the east side of Macclesfield, similar in character to the stratified clay at the 500-foot level. A good section may be seen at a brick pit on the Buxton Road near the canal bridge, where the clay is overlaid by gravel and sand, which formed an ancient delta laid down by a stream emerging from the adjacent valley. Brick-clay at a corresponding level occurs on the west bank of the Bollin near Broken Cross, the inter-

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vening valley being cut down to a depth of about 140 feet. Mr. Pocock.
Although this clay is in some places 40 feet thick, few remnants of it have survived denudation. It was probably of wide extent, and the water in which it was deposited was high enough to overflow the watershed in the Churnet Valley, and connect with the eastern drainage system of England. West of Broken Cross the clay seems to become more stony, which probably indicates that it was formed in a lake between the ice sheet and the Pennine Hills. After the retreat of the waters below the 500-foot level, the river Bollin formed a succession of terraces, on part of which the town of Macclesfield is built. A short distance farther north the river flows outside our area, and its subsequent geological history has not been worked out. After the retreat of the waters below the 500-foot level, the gravel which formed the margin of the lake at the mouth of the Langley valley gave rise to a small brook which flows through Dane's Moss and eventually escapes into the valley of the Dane. Hence the water-parting between the Bollin and the Dane since the glacial period has passed through an old gravel deposited by the former stream. This is a phenomenon frequently exhibited by the small streams in the western part of the area.

The remainder of the drift to be described lies within the drainage basin of the Dane, to the south and west of the Triassic axis before mentioned. The ground level falls gradually from a height of 500 or 600 feet between Alderley and Gawsworth to about 250 feet at Chelford and Withington, and the configuration of these two districts is strongly contrasted. Much of the ground in the former area presents on a small scale the familiar features of hills of circumdenudation and valleys of erosion, which are characteristic of land sculpture among horizontal strata that have been subjected to prolonged denudation; the latter consist of horizontal expanses of clay and sand but little broken, save where the larger streams have cut their channels across them. But the passage from the one type to the other is gradual.

The higher parts of the drift from about 450 feet to 600 feet consist of ridges of sand and gravel, which may be nearly 100 feet thick, with occasional hummocks of clay apparently rising from beneath them. The nature of these deposits is not very clear, partly on account of their denuded condition, and partly from the lack of any good sections.

The group of sand mounds in the parishes of Henbury and Gawsworth may have been formed by the flood waters liberated from the ice sheet, as it retreated further and further from the high ground, while the clay hummocks may be *moraine profonde* formed while it was still in motion on the plain.

At a somewhat lower level the character of the drift becomes more apparent, and phenomena are presented similar to those described in the basin of the Bollin, but on a smaller scale, and of a later geological time. Platforms of clay at successive levels may be traced for considerable distances across the country, the higher ones small and broken, the lower of greater extent.

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Mr. Pocock. As they are followed into the higher ground, these clays disappear between beds of sand and gravel, or are laid against higher platforms. Towards the plain they are cut off by denudation and split up into outliers. These clays are of a chocolate brown colour, rather sandy, and free from pebbles. They are not so conspicuously laminated as some of the clays of the Bollin basin, but they are usually interbedded with sand, and can be followed for considerable distances at a nearly uniform level. They are not more than 20 feet thick, and sometimes much less, especially on their inner margins. Owing to extensive denudation they occupy small areas, though sometimes they exceed in thickness the clays which cover large tracts of the lower ground further west.

A good section of these clays can be seen at Buck's Hill, between Siddington and Thornycroft Park. This is a small round hillock about 300 yards in diameter, the top of which is 410 feet above the sea. A pit on one side shows a bed of sandy brown clay free from stones, about 15 feet thick, resting upon sand. The summit is a rather coarse gravel composed of erratic pebbles resting on an eroded surface of the clay. This is an outlier of a clay bed which, with its overlying gravel, can be traced at nearly the same level all across the area from Henbury to Marton. Between Marton and Gawsworth the gravel forms an extensive terrace.

This and other terraces at various elevations are clearly water levels of Glacial age and may have been formed in somewhat the same fashion as those described by Prof. J. Geikie in the Clyde basin (*Great Ice Age*, p. 175); *viz.*, in a lake bounded by ice on one side and by rising ground on the other. But there is no certain trace of ice action in the clays, and so far as the evidence goes they might have been laid down in a lake which covered the greater part of the Cheshire plain, the successive terraces being different stages in the retreat of the waters. The various little streams which intersect the drift in this part of the area usually have remnants of sand and gravel terraces along their banks, which can be traced down their courses and connect with the lake terraces on the more open ground. These streams take their rise in the more elevated part of the drift, so that the terraces connected with them must be of later date than those formed by the Bollin. A succession of them may be seen on the sloping grounds east of Capesthorne Park, the lowest of which claims particular notice, as it is the connecting link between the more hilly drift just described, and the flatter drift to the west. Beginning as a narrow strip of sand raised above the stream which flows through Capesthorne Park, this terrace rapidly opens out westwards, and covers many square miles in the townships of Chelford, Withington and Kermincham. It consists of fine reddish sand of variable thickness, but generally not more than 8 or 10 feet. Eastwards, it protrudes long tongues up the little valleys near Alderley Park and Siddington, becoming more gravelly and rising in level, as it is traced up stream. Westwards, it is gradually replaced by a clay of about the same

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thickness, which covers the greater part of the ground between Peover and Goostrey, and passes into the area mapped by Mr. Howe. Mr. Pocock.

Sections of the clay can be seen near Kermincham Lodge and Withington Green. It is a dense brown clay with faint traces of lamination, and containing a few striated boulders. Though it is no thicker than some of the clays in the hilly drift, it covers a far wider surface, and is comparatively little denuded. In some places it passes almost imperceptibly into sand. Elsewhere, as in the Peover Brook, near Withington Park, it may be seen with sand beds above and below. Water seems to have been the principal agent in its formation, but the Northern erratics, which it contains, show that there was an ice-front near enough to send its ice floes across the lake, and drop its stony *débris* over the muddy bottom.

The drifts of the whole area now described present a continuous story of denudation and redistribution of sediment at successively lower levels, the later stages of which were undoubtedly accompanied by glacial action, and the whole of them are subsequent to the retreat of the ice from the Pennine Hills. But whether the ice disappeared and a temperate climate supervened in the interval, the evidence collected in this area alone does not suffice to determine. That the interval was a long one may be inferred from the amount of denudation which took place. Before the deposition of the flat drifts in the west, the tiny brooks in the hilly drift cut deeper gorges, and removed more sediment than the larger streams have since accomplished in the lower ground.

## RECENT DEPOSITS (CHESHIRE).

Along the Dane valley river-terraces are well developed. In the plain they are often made of sand and loam, and less frequently gravel; but on the higher ground of Bosley they are invariably composed of gravel, which is usually rather coarse, and merges gradually into the surrounding drift. These terraces occur at varying heights. Sometimes they constitute the present banks of the river, or else they lie some distance above the present river course, and rest on ledges on the steep walls of the valley. At Somerford Park a coarse river gravel lies on the edge of the plateau, fifty feet above the present alluvium. East of Eaton Hall the highest terrace on the west side of the river can be traced for a great distance; it is unusually broad, and consists of sand and silt. The different terraces show unmistakably the formation of the present valley, which is proved to be newer than the laminated clays. Mr. Howe. Mr. Wedd.

Alluvial terraces are beautifully developed along the entire course of the Dane. They are so little liable to flooding, that they are cultivated in places where the banks are high. Nearly all the streams have narrow fringes of alluvium, while many of the shallow depressions in the drift have their bottoms filled with like material.

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Mr. Gibson. Mr. Gibson observes the curious fact that these hollows and the tributary streamlets of the Dane and Wheelock rivers, converge towards the salt-bearing regions of Middlewich and Wheelock; showing that, unless the phenomena are accidental, the brine pumping has not initiated, but only assisted, the surface sinking.

Peat has accumulated in the hollows formed in both clay and sand, and has given rise to extensive mosses. Some of these still exist, but in many, notably Warmingham Moss, the peat has been completely cleared off.

### ECONOMIC GEOLOGY.

Mr. Gibson. In the Cheshire district the absence of good road-metal is a serious inconvenience. The main roads are repaired with material brought from Penmaenmawr, while for second-class roads the Crowstones of the Lower Carboniferous series to the east are frequently used.

The drift clays are extensively used for brickmaking, round Crewe, and to the north of Congleton, and to some extent round Sandbach and Holmes Chapel. The sands yield building sand.

Taken generally the clays are devoted to pasture, the sands to tillage. Crops in the sand area, suffer more from drought than those composed of clay. In the latter, the numerous ponds, chiefly of artificial origin, are of much service, for though shallow, few dry up, and many show only a small diminution in the volume of water. In a few instances, where a thin capping of clay overlies sand, the crops suffer little, as the clay prevents evaporation.

The main water supply of the district is obtained from the sands. It is however insufficient, while the water is hard, and liable to contamination. Sandbach and Holmes Chapel obtain their supplies from this source, but Crewe town is supplied from the boring in the Trias near Whitmore Station.

In North Staffordshire the gritstones of the Third and Fourth Grits have been largely used for building, and for the stone fencing of the district. The Fifth Grit of Heaton has also been quarried; while the lower sandstones of Lask Edge and Brown Edge are used for road material. The black shales of the Lower Carboniferous, and the Boulder-clay on the west of Lask Edge are used for brickmaking. A water supply for local purposes is obtained from the drift-sand.

## 2. Southern District.—Devon and Cornwall.

Mr. Clement Reid, F.R.S., District Geologist.
Mr. W. A. E. Ussher, Mr. J. B. Hill, Mr. E. E. L. Dixon } Geologists.

### ORDOVICIAN AND SILURIAN.

Mr. Reid. Though the year's work has not led to the discovery of palæontological evidence proving the Silurian age of any of the

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killas in West Cornwall, yet as the mapping advances the succession of the rocks becomes more clear, and the probability of the Silurian date of extensive tracts becomes greater. It will be remembered that in former *Summaries* Mr. J. B. Hill divided the older rocks into four series, the oldest of which has long been known to yield Ordovician fossils. Above these Veryan beds come in succession the Portscatho slates, the Falmouth slates, and the Mylor series. Another lithological division, which continues the upward succession northwards may now be added, and may be termed the Hayle sandstone. It consists of thin-bedded, coarse, more or less felspathic sandstone, alternating with fine-grained black slate or shale, which latter resembles in character the shales of the Mylor series below. These four divisions, lying above the Ordovician, are provisionally referred to the Silurian, and it is hoped that the work of the coming season may enable us to show definitely the relation of the highest member to the fossiliferous Devonian of North Cornwall. Mr. Reid.

As the geological structure of West Cornwall is very obscure, it will be necessary to refer in more detail to the evidence on which this order of succession is founded; for, at first sight, the new division appears to pass under, not over, the Mylor series, and that view was taken by De la Beche in 1839.* Before discussing this matter, however, reference may be made to the newly mapped Silurian areas which were examined during the past year. The most convenient mode of doing this will be to commence with the oldest rocks, which occur in the area east of Falmouth, and work westward and northward to the newest division which has yet been mapped on the north coast.

The examination of the Gorran Haven coast sections by Mr. J. B. Hill has proved the further north-easterly extension of the Veryan series as far as that locality. It is interesting to note that the pillow lavas of Mullion Island were found at Gorran Haven on a similar geological horizon associated with limestones and quartzite. Further, although these pillow lavas had not been previously observed at this locality, Mr. Howard Fox† had discovered radiolarian beds in their immediate neighbourhood, still further linking them with the Mullion Island rocks. Although the Gorran Haven rocks have suffered much mechanical deformation and are in part converted into crush conglomerates, their characteristic appearance in the field is still preserved, and their identity is still further confirmed by microscopic sections. Besides their occurrence in these two localities, pebbles of this rock are common in the miscroscopic slides of the conglomerate at Nare Point, intermediate between Mullion and Gorran. They occur, therefore, along a line nearly 30 miles in extent, and their occurrence amongst the fossiliferous rocks of Gorran suggests that their age may be Arenig, corresponding to the age of precisely similar rocks occurring at Ballantrae on the coast of Mr. Hill.

* *Report on the Geology of Cornwall, &c.*, p. 100.

† A paper on "The Radiolarian Cherts of Cornwall." *Trans. Royal Geol. Soc. Cornwall*, vol. xii., 1896.



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Mr. Hill. Ayr, which Mr. Hill had the opportunity of examining in September. Their resemblance in these two areas, separated by a distance of 350 miles, is so remarkable that it is scarcely possible to distinguish them, whether we consider their mineralogical character, their unique appearance in the field, or the rocks with which they are immediately associated. The rocks of Mullion Island have mainly escaped metamorphism on account of the protection afforded by the massive rocks of the Lizard region, which have preserved them from the effects of the earth stresses from the south-east.

The Nare Point conglomerate which separates the Veryan and Portscatho series has been referred to by Mr. Hill, in a former report,* as the possible line of demarcation between the Upper and Lower Silurian. It contains fragments of pillow lava as well as of the quartzite; and as the boulders of the latter were in the condition of quartzite at the time of their deposition, the break indicated by this conglomerate probably represents a protracted interval. The conglomerate also contains foliated igneous rocks, some of which have certainly been derived from the Lizard area, so that we have in Cornwall at least two periods of metamorphism, one of which is prior to the formation of the conglomerate, and its included pebbles of pillow lava, and one later. Of the age of the former we have no evidence, except that it must be pre-Arenig, while the latter is posterior to the Culm measures.

The mapping has been restricted mainly to the Portscatho, Falmouth, and Mylor series, proving the further extension of these divisions, which are provisionally regarded as Silurian. The lithological characters of these divisions have been described in former reports. While folding is everywhere apparent, the bedding can usually be detected, as well as the cleavage. The hade of the cleavage is S.S.E., and it crosses the strike of the bedding somewhat obliquely. Judging from the data furnished by the country between Truro and Gerrans Bay, there are grounds for believing that the stresses which have folded and cleaved the slates proceeded from S.S.E. to N.N.W.

Mr. Reid. The Mylor slates have now been traced westward and northward to Land's End and St. Ives Bay. Over the greater part of this area they retain a very uniform character, except for the variations caused by contact metamorphism. They consist mainly of soft shales or slates, black or dark-coloured when broken across, but more or less silvery on the surface of the laminæ. In places they alternate with very fine-grained sandy silts, but thus far they have shown no indication of contemporaneous volcanic activity, though intruded sills of greenstone are not uncommon.

Throughout this area the strike of the axis of the sharp folds runs about N.E. and S.W.; but as the limbs of the folds are nearly parallel, and are vertical or have often a high southerly

* See *Summary of Progress* for 1899, p. 95, and *Trans. Royal Geol. Soc. Cornwall*, vol. xii., Part 6, 1901.

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dip, it is not easy to make sure of the true succession. In order to ascertain which was top and which bottom in the Mylor slates, the junctions with the sheets of greenstone were examined; but it was found that in every case in which the relations could be made out the greenstones were true sills, with contact metamorphism above and below. As fossils are absent, the only other way of deciding the question lay in working out the geology in such a way as to distinguish the general structure from the sharp plication above alluded to. Mr. Reid.

The sills of greenstone round the Land's End granite give a valuable clue. They are so thick and massive that they have resisted the plication, though they are often much sheared and full of small thrust-planes. Everywhere these sills dip away from the granite at an angle which apparently does not differ greatly from the slope of the granite surface below. Further, in the neighbourhood of Penzance and Newlyn one thick sill (at least 80 feet through) caps a series of hills in such a way as to show that it, and the associated slates, though disturbed are not overturned. Next, various slight indications suggest that the thick sills on the north coast and the sill which caps the hill near St. Erth may be on nearly the same horizon, even if they are not parts of the same sheet isolated by denudation. If this evidence goes for anything, and the sills keep approximately to the same horizon in the Mylor slates, we are apparently dealing with a mass of slate of only moderate thickness, folded and constantly repeated in small anticlines and synclines, and having probably a slight general dip towards the north. This view seems to be borne out by the similarity of the killas at Penzance and St. Ives, and its striking uniformity over the wide area between Ludgvan and Gwinear.

On tracing the killas eastward from Carbis Bay along the coast, however, its character alters somewhat, and after passing a thin greenstone sill of different appearance, we come to lighter-coloured killas, sometimes banded with green, and containing a larger proportion of fine silty sand. A pit near the western edge of the West Cornwall Golf-links shows sheared, coarse-grained, soft, highly-felspathic sandstone, with few or no grains of quartz sand. These soft, felspathic beds have been taken as the top of the Mylor slates, though they might equally well have been considered as the base of the hard Hayle sandstones which come on immediately above. Unfortunately the cliff face, where the junction should be seen, is now smothered with dune sand, and nearer the Hayle River the cliff is entirely composed of alternations of sandstone and shale. The boundary strikes southward to Lelant, then crosses the river near Hayle—unfortunately not showing clearly in the low river-bank. Next it passes through the overgrown railway-cutting south of Hayle, one end of this cutting being in dark slate, the other in light-coloured shaley sandstone. Then, following the normal strike, the boundary passes under the valley deposits north-eastward to Phillack, a good section of the felspathic top of the Mylor slates being



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Mr. Reid. visible in a new road-cutting at Bodriggy, between Hayle and Copperhouse. Excellent sections of the sandstone are seen in Black Cliff, and also in the old quarries and river-bluffs around Hayle Harbour. East of Phillack the boundary turns sharply northward, through the Towans to the coast, being readily traceable across the dunes by the mine-tips. East of Godrevy the Hayle sandstone reappears with the normal east-north-east strike, though much folded. No trace of igneous rocks, either contemporaneous or intrusive, has yet been found in the sandstone; and though careful search was made, no fossils could be discovered. Even the worm-tracks and borings, and the so-called fucoids, so often occurring in Palæozoic sandstones, appear to be absent.

The junction of the Mylor slate and the Hayle sandstone is described in some detail, for the curvature of the strike yields the best evidence for the true order of succession. The normal strike of west Cornwall is north-east and south-west, but the uplift caused by the intrusion of the granite of the Land's End has everywhere caused the killas and its interbedded sills to dip away from the granite mass. This uptilt, at right angles to the strike, must necessarily divert the strike at Lelant, where the influence of the granite begins to be felt, towards the north, if the Mylor slate underlies the Hayle sandstone; but it would be diverted towards the south if the Hayle sandstone were the older of the two. As a matter of fact the diversion of strike is to the north. North-east of Hayle there is another northward diversion of the strike, apparently unaccounted for by any granite intrusion. But here, also, the diversion seems to be caused by a granite intrusion; for Mr. Dixon has discovered between Gwinear and Gwithian a metamorphic area, which seems to point to a buried boss of granite not far below. No doubt the true junction of the Hayle and Mylor series should be drawn as a sharp zig-zag line; but not being able to trace these minute details inland, we can only follow the general strike, the variations of which bring out thus clearly the true succession.

The greenstone sills which form so marked a feature in the Mylor slates of west Cornwall, have now been mapped throughout the country west of Camborne. The rocks, however, vary so much in original lithological character, and the superimposed shearing and contact metamorphism have caused so great changes, that it seems advisable to defer any fuller description of these rocks for a future *Summary*, when the petrological work will be further advanced.

### GRANITE.

Though the granites of west Cornwall, like those of Devon, are probably of late Carboniferous date, yet as those examined last season are everywhere in contact with the Mylor slates, it will be convenient at this point to deal with them and with the metamorphism they cause. Here, also, the petrological evidence

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will be left for a future report, the field evidence only being mentioned in any detail. Mr. Reid.

The general character of the Land's End granite and the character of its intrusive junction with the killas are so well known that it is needless to repeat the description.* A few points of interest noticed in the course of the new survey are, however, worthy of remark. In the first place it has been found that the Land's End mass is not all of one age or type, but includes an area of about seven square miles of a fine-grained granite of later date, which extends from Gulval Downs nearly to Zennor on the north, and from Amalebrea to Carnaquidden on the west. This granite is so fine-grained that it is commonly known as "whetstone" or "sandstone." Its composition is very similar to that of the coarse granite into which it is intruded. It is a buff or grey biotite granite with small (half-inch) scattered crystals of orthoclase and rarer crystals of pinite of about the same size. Its boundary is everywhere sharply defined, but there is no section showing the actual junction of the two rocks, though at its northern limit at Beagleton Downs loose blocks on the moor show numerous veins of this fine granite penetrating coarse granite of the common Land's End type. The newer granite forms undulating land, surrounded by tors or carns of the coarser type, but itself neither forms carns nor weathers into large rounded masses like those which nearly everywhere encumber the ground outside its limits. It tends to weather into small angular blocks, which are easily removed and are more convenient for building. The farmers consider the land to be of better character, but it could not be ascertained clearly whether this was due to any difference in the composition of the soil or merely to the greater convenience for working where large boulders were absent.

Much of Penzance is built of this fine-grained rock, with dressing of the ordinary coarse granite. Thus far only the buff rock near the surface has been used to any extent, but below fifteen feet the Castle on Dinas quarry shows an excellent grey stone, which ought to be of considerable value.† The Gulval Downs rock, however, does not split in the same way as the older granite, and appears never to be used for lintels or gateposts, even close to the quarries. It is used locally for road metal, and is better than the coarse granite, but not equal to the greenstone.

The Land's End granite (as distinguished from the newer Gulval Downs granite) is remarkable for showing a distinct but irregular bedding structure, which seems to be approximately parallel to the granite surface where the granite passes beneath the killas. This bedding is very conspicuous on the weathered carns or in the cliffs. It is apparently due to the orientation of the large felspar crystals, which, during the movements of the molten rock, have tended to arrange themselves parallel to the surface past which they flowed. The structure cannot well be

* See *Summary of Progress* for 1899, p. 87.

† See also De la Beche, *Report*, pp. 161, 494.

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Mr. Reid. illustrated by hand specimens, though very noticeable in the field, for it is only an orientation of most of the crystals in one direction, not of all of them.

A short distance from the margin, usually less than half a mile away, this bedding, instead of dipping at high angles, becomes almost horizontal, suggesting that the granite overhead had formerly possessed a nearly level roof of killas. On applying this test to parts of the cliff where no killas now fringes the granite, so many places were discovered where the high outward dip was strongly marked as to leave little doubt that the present coast line corresponds very nearly with the original limit of the Land's End granite.

If the granite originally formed so flat a dome, the question naturally arises, What is its contour where hidden by killas? This question cannot yet be satisfactorily answered; but enough has been learnt to show that it often plunges beneath the stratified rocks at an angle of about 45°, though in other cases the angle is only 15° or 20°. Corresponding with the steeper hade, we find a metamorphic aureole fully three-quarters of a mile wide; but where the killas and greenstone transgress over the granite, as at Tremethick, near Penzance, the aureole widens enormously. The boundary of the metamorphic area here instead of sweeping round the bay in the granite, cuts across, suggesting that the whole area around Penzance is underlaid by granite at no great depth.

A metamorphic aureole, three-quarters of a mile wide, with a dip of the granite at 45°, would give a thickness of the aureole, measured at right angles to the cooling surface, of nearly 2,800 feet, and a depth to the granite at the outer limit of metamorphism of 4,000 feet. We do not yet know, however, to what depth this dip of 45° is continued, though in the Levant Mine a dip of nearly that amount has been followed to 1,500 feet below the sea-level, with no sign of any flattening. There, unfortunately, the width of the aureole cannot be measured, as its outer margin is beneath the sea.

Mr. Hill. The aureole of metamorphism encircling the Carn Menelez granite has been studied by Mr. Hill so far as the unsatisfactory nature of the ground would permit. The alteration of the innermost zone, extending to 250 yards from the granite, is so marked that little difficulty was experienced in spite of the lack of good sections. Beyond that zone, however, the evidence of its extension is partial in character. The mineral alteration of the inner zone is more or less complete, Andalusite, Muscovite and Biotite being extensively developed. In the outer fringe the secondary micas are often difficult to distinguish from original constituents, while Andalusite is altogether absent, the hornfels, where it exists, being likewise confined to the inner zone, so that beyond that limit the occurrence of spotted slate is the sole evidence of contact metamorphism, and this is so partial in its distribution that the demarcation of the outer limit of alteration with any attempt at accuracy is impossible. With these "spots," tiny elongated needles, which may possibly be referred to Chiastolite, have been

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observed a thousand yards distant from the granite. Speaking generally, the aureole of metamorphism is about half a geographical mile in width (1,000 yards), but at Penryn Creek the spotted slates form a loop, the outer margin of which is two miles from the nearest visible granite, notwithstanding that the loop is free from elvan dykes. Moreover, the great elvan region which abuts against the granite at Gwennap contains large areas of spotted slate, which, although the spotting is generally of a more minute character than is found bordering the granite mass, it is obviously impossible to differentiate from the other. Spotting has also been occasionally observed in the vicinity of isolated elvan dykes. For the reasons above stated, it will be apparent that an engraved line on the map, to mark the limit of contact alteration in this area, would present such an inaccurate interpretation of an important petrological problem that its omission would be less misleading than its insertion. Mr. Hill.

This question of the underground contour of the granite surface is an important one for the miner, for the occurrence of certain ores, especially tin, is known to be intimately connected with the proximity of the granite. It is interesting therefore to find, as already mentioned, that an isolated metamorphic area has been discovered north of Gwinear by Mr. Dixon, and another around Leedstown. These seem to connect the granite district of Land's End with that of Camborne; but as we have not yet sufficient data for calculating the thickness of the metamorphic aureole, measured at right-angles to the cooling granite surface, we are unable yet to calculate the depth of the granite in metamorphic areas in which no granite is seen. Besides this, the width of the aureole is not the same round the different granite masses; and this variation seems to be due not merely to variations in the hade of the granite surface, but to the different intensity of the metamorphism. The killas close to the Land's End granite, for instance, is intensely altered into knotted hornfels, and the least width of the aureole, measured at the surface, is over half a mile. The smaller mass of the Godolphin granite causes less alteration, and gives a least width of aureole of about a quarter this amount. In striking accordance with this difference, is the strongly developed chilled edge of the Godolphin granite, contrasted with the very slight chilling noticeable round the Land's End mass. It is hoped that further light may be thrown on this question when the numerous mine-plans have been examined and the relation of the ores to the granite surface has been more thoroughly worked out. Mr. Reid and Mr. Dixon.

The Carn Menelez granite, which extends from Penryn to Camborne, was partly described by Mr. Hill last year.* Further examination of the jointing, orientation of the crystals and grain in this granite, shows that over the district generally the orientation is so feeble that it would often escape observation if not specially sought for. Moreover, although there is a general uniformity in the direction of orientation it is by no means constant, Mr. Hill.

* *Summary of Progress* for 1900, p. 107.

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Mr. Hill. and if examination were confined to a limited number of sections the results obtained might be misleading. At Kennal Vale, however, these phenomena are carried a step further, and the parallelism is so marked that it could not fail to be detected by the most cursory examination. It approaches a definite structure, so much so that the orientation is no longer the feeble approach to crystalline arrangement confined to the attempt at parallelism of a sufficient number of the elongated minerals to ensure a grain; but there are definite visible planes set up in the rock which dip steeply towards the margin of the granite, while the rock in places is so foliated that its schistose character can be detected in a hand specimen. The foliation of the granite at Kennal Vale agrees in its trend and general hade with the corresponding planes in the slates which flank its margin.

Following the granite boundary 1½ miles further in a S.S.E. direction, we find at Treluswell, near Penryn, two foliated granitic sills flanking the granite about 30 yards distant from its margin. Their foliation planes correspond with the cleavage planes of the slate between which they are intercalated. Microscopic examination (3364) shows them to be granite and to be allied to that rock rather than to the elvan dykes, with which their mode of occurrence would otherwise suggest their correlation. Their N.N.W. direction, moreover, parallel to the granite boundary is nearly at right angles to the trend of the elvan dykes of the district. The evidence suggests their modification by pressure before final consolidation. There is unfortunately no available section of the granite mass adjoining, so that the nature of its margin at this locality cannot be investigated. The foliation of the granite sills agrees with the foliation of the granite at Kennal Vale, and both correspond in direction to similar planes in the adjoining slates. It has been pointed out that the deformation of the slates is the result of lateral movements acting from S.S.E. to N.N.W. It will be immediately seen that this direction agrees with one of the orientation planes which is common to the whole of the granite—further it corresponds with the foliation of the granite at Kennal Vale and of the granitic sills at Treluswell. We have strong reasons therefore for the assumption that the granite irruptions and the earth movements are not only closely related but that the movements had not ceased to operate before the final solidification of the granite.

Mr. Reid. In the Land's End and Godolphin granite masses no evidence has been found of the foliation or schistosity such as is described by Mr. Hill as occurring in the Carn Menelez granite. There is fluxion structure towards the margin; but the fluxion is parallel to the curved cooling surface, not parallel to the cleavage or other structural planes in the killas. The only sign of contemporaneous or subsequent movement that could be found, besides small faults, is a jointing approximately parallel with the strike of the contortions in the killas. Fractures along planes of weakness in sedimentary rocks, must, however, tend to extend across intruded crystalline masses, and the subsequent intrusion of the elvans along these particular planes seems to show that they did so in West Cornwall.

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## ELVANS.

The mapping of the elvan dykes in West Cornwall is giving a great deal of trouble, for they are so abundant in most of the mining districts that it is important to ascertain what relation they bear to the metalliferous lodes. These dykes with few exceptions rise along the line of strike of the folds in the killas, which also happens nearly to correspond with the strike of the cleavage. They seem to be intruded along planes of weakness, and are probably connected with granitic masses below; they do not radiate from the granite bosses seen at the surface. In lithological character they vary considerably, though a common type of elvan somewhat resembles the fine-grained granite of Gulval Downs. It cannot yet be proved, however, that any of these dykes are contemporaneous with this granite. Some of them penetrate the older granite, but none can be found near the newer mass, which, however, appears in an area in which no elvans occur. North-west of a line drawn from Whitesand Bay through Hayle north-eastward, elvans seem to be absent. Mr. Reid and Mr. Dixon.

Though several of the elvans are schorlaceous and metalliferous, this impregnation seems to be a metamorphic change belonging to a late stage. Two series of intersecting elvans, near Rosewarne and Gwinear, have been examined by Mr. Dixon. He finds that an older series of non-metalliferous quartz-felsites, having a fairly constant north-east and south-west strike and northerly hade, is cut by a newer series of almost non-porphyritic felsitic dykes of somewhat different character, having a more westerly strike, and in some cases, at least, having a hade to the south. These newer dykes are schorlaceous and metalliferous, or are closely associated with metalliferous lodes in the killas; the older dykes, on the other hand, appear only to contain ore where they come within the influence of the newer group.

The elvan dykes are very unevenly distributed over the area north of Falmouth, examined by Mr. Hill. They attain their greatest development in a belt of country extending from the granite margin at Gwennap through Perranarworthal to Kea, diminishing in extent towards Truro—beyond which place in the ground mapped as far to the north-east as Probus they have not been noticed. Similarly in the region lying to the south-east of Gwennap, except for a small group in the neighbourhood of Penryn, their occurrence is insignificant. It may be noted that the belt of elvans between Gwennap and Kea marks the beginning of the great metalliferous region extending from Gwennap to Camborne. In this elvan belt, the quantity of vein quartz is so enormous that the soil is materially impoverished, and over a great portion the slates contain knots, although far removed from the nearest visible granite—the knotting, however, is of a more minute type than that displayed in the aureole of metamorphism which flanks the granite. The Gwennap group of elvans has not yet been traced as far as the granite margin, but in the district lying to the south-east one elvan only has been traced within the granite. It has been followed for over a mile from Towntanna Mr. Hill.

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Mr. Hill. to Trevales. In size, the elvans range from a few feet to many yards in thickness. A dyke, however, of abnormal dimensions has been traced following an east and west course through Gwennap, and attaining a width of 150 to 200 yards. This dyke has been followed for two miles, and its westerly extension towards the granite margin has not yet been reached. The general direction of the elvans is north-easterly to east-north-easterly. Their hade is usually very steep, and so far as observations have gone they appear to incline more frequently to the north-west than to the south-east. They exhibit, however, much variation in this respect, and sometimes lie nearly flat. They vary considerably in texture, from extremely fine types to examples so coarse that their porphyritic felspars may attain a size of ¾ inch. The felspars consist of both orthoclase and plagioclase. Quartz occurs in blebs, and often with a bipyramidal habit, crystals sometimes exceeding ¼ inch in size. White mica is more abundant than biotite, occurring not only as an original constituent but as a decomposition product of the felspars. A characteristic feature of the elvans is the tendency for the white mica to assume a radiating or plumose habit, and in the matrix of the rock to combine with the felspar in forming a pegmatitic structure. This granophyric habit in connection with the white mica is general amongst the elvans. It is not confined to the micro-pegmatitic type, but pseudo-spherulitic structures are also noticed. Felspar and quartz occur as crystals of an earlier generation than the matrix. Not only are the crystals penetrated by the ground mass, but there is a tendency for silica to aggregate round the quartz grains. The felspar shows a marked tendency to decompose, much white mica being developed as an alteration product. In some instances the plagioclase may be noticed altered to white micaceous substance, while the potash felspars are little decomposed. The decomposition of the felspars proceeds often from the central core, and selvage edges of shrinkage have been observed bounding the felspar crystals.

### CHINA STONE.

Mr. Reid. The china stone is granite altered, and with its felspar kaolinised *in situ*, apparently by the solfataric action of fluoric and boracic vapours. This decomposed granite occurs, as is well known, in enormous irregular masses or pipes which seem to have an indefinite downward extension—at least they show no sign of narrowing at the greatest depth to which they have been worked. The distribution of these masses is peculiar, and strongly supports the view that they represent channels along which the vapours escaped. There is one mass in the middle of the Land's End granite about midway between Penzance and Cape Cornwall; there is another mass in the centre of the area of newer granite now first recognised. A third mass occurs about the middle of the Godolphin granite. In each case a vent seems to have occurred in the highest part of the granite dome, and only one such vent has been discovered in each boss. Whether this rule will hold good for other districts remains to be seen.

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## DEVONIAN.

Mr. Ussher has been engaged on the Devonian rocks of east Cornwall, completing the survey of the new series map sheet 348, and carrying the work westward into the adjoining sheet 347. The strata mapped embrace all the Lower Devonian divisions, Middle Devonian slates and slaty mudstones, and in the neighbourhood of Quethiock slates and schalsteins which may belong to the Upper or Middle Devonian, or wholly to the former group. The Lower Devonian rocks are the westerly continuation of those of the Looe area. Up to 1901 the Lower Devonian succession had never been satisfactorily established, an unbroken sequence of the constituent subdivisions having been nowhere encountered. Mr. Ussher.

A few days devoted to the comparison of coast sections has greatly facilitated field work during the last two months of the year, and coupled with the identification by the palæontologist of the fossils collected in 1900 in the Torquay promontory, has yielded more satisfactory results than have heretofore been obtained. These results have a direct bearing on every Lower Devonian district in South Devon, and will, it is confidently expected, much facilitate future work in Cornwall.

The year's work in the field, and in reviewing the evidence, tends to place the Dartmouth slates at the base of the Lower Devonian. These slates often exhibit pronounced green and purple tints, and delicately blended mottling of purple and pale purple and grey; but these characteristic colours often give place to buff and drab tints, and grey, and even blackish slates may be found. The slates are often siliceous; they present glossy surfaces and contain beds of very hard grit and arenaceous rocks. The hard grits or quartzites, both in the area east of Fowey, and in the Kingswear promontory, locally result from the amalgamation or welding together of siliceous shales or slates. On the whole, the aspect of Dartmouth slate sections suggests a coincidence between bedding and cleavage; but when attempts to procure cleavage-dips are made, the angles of schistosity are found to vary, and occasionally hard grits are seen to cut off the planes of schistosity in the slates. From many indications of local irregularities, there can be little doubt that the slates of this series, where they seem to present a continuous succession, are constantly repeated by sharp folds which have been broken and sheared out. In the coast west of Polperro and south of Lansallos, the association of grits in the slates is the same as that displayed on the Revelstoke coast. Many contortions are exhibited by them, including the vertically zigzagged bedding so frequent in the Devonian rocks of south Devon and east Cornwall. These slates have now been traced from the Kingswear promontory westward to the Fowey estuary. In this extension their persistence is only broken near East Allington, in the Kingsbridge area.* The problem of the geological

* See Map in Rep. of Easter Excursion, 1901. *Proc. Geol. Assoc.*, vol. xvii., p. 121.

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r. Ussher. structure of Cornwall, south and west of a line between Fowey and Watergate Bay, is precisely similar to that of the Kingsbridge and Torcross area, in both cases we have partly fossiliferous rocks on the south of the Dartmouth slates. What are their relations to the Dartmouth slates: are they newer or older? If the former these slates must be regarded as an anticlinal; if the latter, as an outcrop, any impersistence in which can only be explained by fault or change in character.

In the *Summary of Progress* for 1900, pp. 60, 61, reference is made to fossils collected in the Torquay promontory, the Kingsbridge area, and the Looe area; the results of the examination, re-examination and comparison of these fossils were received from the Palæontological Department in January, 1901, together with a list of fossils collected by Mr. Upfield Green, from Looe and Fowey.

From these lists the following fossils may be taken as characterizing the Looe and Fowey fauna:—

| | |
|---|---|
| Orthotetes hipparionyx | Rhynchonella pengelliana (scarce) |
| Spirifer primævus | Pleurodictyum problematicum |
| Streptorhynchus gigas | |

In the badly preserved fossils of the Kingsbridge area (Ringmore beds) all the above except *Rhynchonella pengelliana*, have been recognized as far as the condition of the crushed casts and impressions would permit. In the Torquay promontory (New Drive) *Orthotetes hipparionyx* occurs in a fossiliferous horizon containing numerous fragments of spined *Homalonotus* and casts of *Strophomena latecosta* (also in the New Cut and on Oxlea Hill). *Spirifer primævus* was found in the Meadfoot beds near Hopes Nose with a *Homalonotus* resembling *H. Rœmeri*, *Strophomena rhomboidalis*, Zaphrentidæ, &c. *Rhynchonella pengelliana* was doubtfully identified by Mr. Etheridge among fossils collected by Champernowne from the New Cut. Davidson thought that he recognised it amongst fossils collected by Mr. Whidborne in the Saltern Cove railway cutting. *Streptorhynchus gigas* is given in Tawney's lists amongst fossils collected west of Hopes Nose Raised Beach, presumably from the uppermost grits of the Lower Devonian. *Pleurodictyum problematicum* is common in the Torquay promontory, and confined to no special horizon. As the Lower Devonian rocks of Torquay and Paignton are all above the Dartmouth slates, which do not appear at the surface, and palæontological evidence is all in favour of the correlation of the fossiliferous strata with those of the Looe and Fowey area, which unquestionably are represented in the Kingsbridge area, it follows that the Dartmouth slates are the lowest member of the Devonian of South Devon and of Cornwall as far west as the Fowey estuary.

The Torquay promontory is, perhaps, the worst tract in the south-west of England to obtain evidence of the actual sequence of the Lower Devonian rocks, owing to faults and contortion. The coast section south of Brixham has not yet been actually

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compared with the Plymouth and East Cornwall sections, and the comparison of the Ringmore section is not yet completed. In both these sections the Dartmouth slates appear to be in contact with dark slates, which in the Ringmore section pass up into the fossiliferous beds. Mr. Ussher.

In the Plymouth section the practically unfossiliferous Staddon grits are well developed; they rest on grey slates with hard grit beds and bands, presenting at Boveysand the same relation of pronounced cleavage broken by bedding planes that is so pronounced in the grey slaty siliceous rocks forming the coast line between Fowey and Pencarrow Head. The grey slates succeeding these beds in the Plymouth section contain *Zaphrentidæ*, and in parts of the section the bending or distortion of the cleavage planes at intervals is the only indication of bedding. At the south end of Crownhill Bay the slates become calcareous and pass into red very fossiliferous decomposed friable slaty beds crossed by limestone bands containing monticuliporoid corals, &c., identical in all respects with the red and grey limestones associated with the Looe beds at East Looe beach and at Millendreath. These beds are associated with hard fine-grained grits of the same type as those at Beesands, south of Torcross, and they are faulted against the Dartmouth slates at Andurn Point. This faulted north boundary of the Dartmouth slates extends eastward to Modbury.

Turning to Tregantle on the Cornwall coast, we find a great development of the fossiliferous beds identical in every respect with those of the Plymouth section, which when traced inland are seen to contain the same grit types as at Looe and in the New Cut near Torquay. Between these beds and the purple and green mottled Dartmouth slates, on the east and on the west, grey and dark grey slates, with grit beds and arenaceous interbanding in part, form the cliffs. Traces of *Pteraspis* have been found in these slates toward Portwrinkle, so that in part they belong to the Dartmouth slate series, and form a passage into the overlying beds of the Meadfoot series. In the *Summary of Progress* for 1899, page 84, these slates are referred to, and their connection with the Bindown and Congorlan quartzites is correctly foreshadowed. During the latter part of the year 1901, general boundaries were drawn in the area between Lanreath and Polperro separating the grey slates and grits from the variegated Dartmouth slates on the one hand, and from the more or less fossiliferous slates and grits which represent the Looe beds on the other. The latter is a purely tentative line and could not be continued eastward, but there are indications of the development of the local characters of this intermediate series westward. Just north of Lanreath the Dartmouth slates appear in an impersistent mass or masses cut off by a fault on the north, and bounded by dark slates on the south. Here, therefore, as at Bindown and Congorlan the Dartmouth slates appear on the north of the fossiliferous Looe rocks, in which, although there are evidences of crinoids and occasional fossil traces (in slates of Ringmore types), few markedly

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Mr. Ussher. fossiliferous beds were encountered, probably owing to the absence of good exposures. The grey slates with hard grit beds and arenaceous banding are, however, well evidenced, both on the north and south of the Dartmouth slates, which they separate from the fossiliferous grits and slates of Pencarrow Head, rightly correlated by De la Beche with the fossiliferous rocks of Looe. The Dartmouth slates would therefore appear to form an anticlinal 1½ miles in breadth, bounded by practically unfossiliferous slates, grits, sandstones, and interbanded argillaceous and arenaceous rocks, which for convenience of reference may be provisionally termed Lower Meadfoot beds. An interesting section of these beds is afforded by the south shore of Point Pill Creek, where they are faulted against purple and green Dartmouth slates on the north. In this section grey and dull greenish-grey slates, variegated with buff and straw-coloured tints, and in places associated with beds of tough buff silty rock, and occasionally of hard grit, strongly resemble the variegated slates and arenaceous rock of Mr. Hill's Falmouth series. A faulted development of buff or silty rocks of a type common in the Pelynt district occurs in them. Grit beds here and there show sharp folding, and in one place a mass of tough dense grey grit suggests the local development of beds similar to those of Bindown and Congorlan. Near Brawn Point blue and straw-coloured slates exhibit cleavage planes dipping at a low angle with small wavy undulations due to the intersection of slightly harder silty intercalations. Near this, fossiliferous beds come on which include thick bedded yellow-brown arenaceous rocks, in part very similar (honeycombed with distorted fossil cavities) to the fossiliferous beds of the Tregantle and Plymouth coast sections, and on the same line of strike with the fossiliferous beds of Pencarrow Head.

It is important to note that an argillo-arenaceous or silty character, similar to that displayed in the Point Mill Creek section, is frequent in the Looe area, and in the absence of fossils this deterioration of grits, belonging to the fossiliferous series, cannot be distinguished from similar associations in the Lower Meadfoot beds. The Staddon grits exhibit a similar deterioration traced westward, being locally an argillo-arenaceous series in which more or less silty mudstones predominate over the harder grit beds. The assimilation of different horizons in the Lower Devonian, through the assumption of practically identical lithological characters, renders the mapping extremely difficult and most unsatisfactory where faults have to be drawn, as is the case with a west-south-west fault cutting out the Dartmouth slates of Bindown and Congorlan, which is shifted by an exceedingly indefinite cross fault, and in further prolongation forms the north boundary of the patch of Dartmouth slates north of Lanreath.

### CARBONIFEROUS.

Mr. Teall's microscopic examination of the Wearde grauwacke and similar beds at Forder Lake, both near Saltash, proves that

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these rocks are made up of quartz, felspar, fragments of felsitic and (locally) andesitic igneous rocks. His examination of Culm grits from near the River Tavy south of Abbey Bridge, Tavistock, entirely favours the correlation of the Wearde Efford rocks with the Culm grits (base of Middle Culm Measures), as suggested by Mr. Ussher.* The conditions under which they were formed are explained in the paper here quoted. Mr. Ussher.

During 1901 exceptional opportunities for observing these beds were afforded by the cutting of a new road south of Lower Compton village, and in a deep section driven northward into the hill on which they are best developed. The grits, in even beds separated by masses of dark shaly slate, vary in grain and hardness, and in places present the character of a fine breccia or tuff containing numerous small pieces of shale. The excavation terminates in a mass of exceedingly hard igneous rock. In Lower Compton road the section begins with vesicular volcanic rock, succeeded by very hard even-bedded grits, with shaly intercalations and coarse and fine fragmental rock containing pieces of shale, &c.

## PLIOCENE.

The survey of the Land's End district has led to the discovery of one outlier of Pliocene deposits besides that already known at St. Erth. The new outlier occurs on the ridge north of Cannon's Town, on the opposite side of the valley to the St. Erth pits, and at an elevation slightly greater (150 feet). It consists merely of the ferruginous pebbly sand or soft sandstone known as "growder," the fossiliferous clays seen in the St. Erth pit being missing. The search for Pliocene deposits has, however, resulted in the discovery of a striking feature in Cornish geology. In describing the St. Erth deposit reasons were given for thinking that the fossiliferous clay indicated a depth of water of 40 or 50 fathoms, and nothing that has since been discovered has led us to modify this view. † If this view is correct we ought to find traces of a Pliocene shore-line near the 400 foot contour, for the fossiliferous clay lies about 120 feet above the present sea-level. When the deposit was examined in 1886 no shore-line could be found in the neighbourhood, for all the country near St. Erth lies below the 400 foot contour, and shows signs of having been planed and smoothed by the sea. Out of this undulating plateau, however, rise in the distance various abrupt and more rugged hills, and the examination of the whole district has now shown that a clearly-defined ancient shore-line bounds this plane of marine denudation at a height of about 420 feet above the present sea-level. Mr. Reid.

Notwithstanding the strong presumption that the plateau was once occupied by Pliocene strata, and that the old cliff marks the

* *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xlvi., p. 50, 1900. See also *Trans. Inst. Mining Engineers*, vol. xx.

† "The Pliocene Deposits of North-Western Europe." *Nature*, vol. xxxiv., p. 341 (1886); The Pliocene Deposits of Britain, "*Memoirs of Geol. Survey*," chapter v. (1890).

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Mr. Reid. former limit of these strata, it is exceedingly doubtful whether the whole of these features were of Pliocene date. The plateau is so extensive, and is cut in such hard rocks, that it is difficult to imagine that the Pliocene sea could have levelled it. Perhaps after all it is a feature of much older date, merely cleaned up and sharpened in Pliocene times. In support of this view, we can point to the very similar plateau in Gower, described in Mr. Strahan's report (p. 49), for on that plateau have now been discovered two outliers of Trias. It is hoped that further work in Cornwall may throw light on this striking feature.

## RAISED BEACHES.

Thus far no Pleistocene deposit older than the raised beach has been recognised in West Cornwall, though there are indications that the whole coast is fringed with a more ancient erratic deposit, which lies entirely beneath the present sea-level. The numerous small erratic blocks which occur in the raised beach probably belong to this older deposit; for nothing has yet been found in the newer one to suggest anything but a temperate climate, and the foreign stones in the raised beach are all sufficiently small to have been brought up during storms from a depth of 5 or 10 fathoms attached to the roots of oar-weeds. The larger blocks, so often found in dredging and trawling, do not seem to occur in the raised beaches.

The highest raised beach yet discovered in Cornwall is seen in Penlee quarry, near Newlyn, where coarse beach-shingle rests on a rocky shelf 65 feet above Ordnance datum. The old cliff and beach can be traced at about this level through Penzance, and sweeping round Mounts Bay behind the marshes. It is recognizable also at frequent intervals round the coast, as a notch and narrow steeply-sloping ledge, more or less hidden by head and talus. Everywhere it yields erratic stones, though these are especially abundant where, facing the raised beach, is found a considerable extent of shallow sea. The foreign rocks are mostly subangular Chalk-flint and Greensand-chert, like the altered rocks found in the Bagshot gravels of Devon, and pebbles of a hard purple sandstone of doubtful origin. These occur everywhere, but at Cape Cornwall was found also a single pebble of biotite-trachyte or biotite-andesite closely resembling some of the Permian volcanic rocks of Devon, though unlike anything belonging to Cornwall.

## WATER SUPPLY.

Another season of deficient rainfall caused great anxiety as to the water-supply of many Cornish towns and watering-places. This question is a very difficult one to deal with, for great part of the country has been so riddled with mines that the water

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drains away far more rapidly than was formerly the case. Besides this, great caution has to be used as to the source of the supply, for though the limited inland population in most of the area examined in 1901 renders it fairly easy to avoid surface contamination, yet the common occurrence of copper-salts in solution necessitates the rejection of many copious sources. Mr. Reid.

Penzance is now undertaking new works for increasing the water-supply by tapping the elvan which crosses the altered killas near Madron. These elvans are often valuable sources of water-supply in Cornwall, though in different cases they behave very differently. The porous much jointed elvan near Penzance forms a dyke in the more impervious killas, and seems to act as a channel, probably conducting a good deal of water from the granite hills above. In other cases, decomposed or kaolinised elvans form clayey dykes which dam up the water, so that its level is much higher on one side than the other.

## SOILS.

The soils over parts of the Land's End district have already been alluded to, but it may be remarked that for market gardening, flower culture, and dairy farming, which are now becoming so important in Cornwall, the nature of the underlying rock and the chemical composition of the natural soil are only two of the requirements. Cornwall depends so largely on the production of vegetables and flowers earlier than, or at seasons different from, other parts of England, that aspect and shelter are even more important than soil, especially as the soil is so freely enriched and altered by heavy dressings of shell-sand and seaweed. Some of the best land for this spade culture is found where the slopes face the sun, as they do around Penzance, and at the same time have a mixed soil of greenstone and killas, lightened by a coarse, sandy wash from the granite above.

Not only is the soil greatly modified by intentional transportation of sea-sand, but it must also be changed by wind-borne dust for much greater distances than is usually thought. Last year, during gusty E.N.E. winds, at Carbis Bay, from a height of 270 feet above the sea, swirls and puffs of dust were seen to rise from the desert-like flat at the mouth of the Red River to a height of at least 240 feet. They nearly blotted out Godrevy Towans (230 feet) and Godrevy Lighthouse, and then spread in a well-defined belt across St. Ives Bay for over three miles to near St. Ives Head, which the belt must have passed.* Soils thus modified by dust and calcareous sand cover most of the rock near Hayle and Lelant.

The *granite* in the Falmouth area forms a dome-shaped tableland and supports a soil adapted for cultivation. Knolls of solid rock appear at random above the soil and on the slopes of the valleys, but apart from these rocky exposures the ground forms good arable land. The disintegration of the granite, however,

* See Reid, *Nature*, March 6, p. 414.



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Mr. Reid. yields a somewhat cold soil, and crops are not so advanced as on the slate-bearing ground.

Mr. Hill. *The Portscatho series* yields a generous soil, which is considerably enhanced by the arenaceous beds, which, keeping the soil from becoming too coherent, admits of the ready passage of the surface drainage. The rocks of this division, however, are everywhere carved into deep valleys, the slopes of which are often so steep that the surface soil is washed off to the lower grounds, resulting in a hill slope comparatively barren.

*The Falmouth series* produces some of the richest land, and this is especially the case where the soft, sandy beds predominate. The presence of so much more iron in its chemical composition will account for its comparative superiority in this respect to the other sedimentary divisions. This division has a tendency to form lower ground, and shows no disposition to the formation of steep valleys, so that barren land within this division is exceptional.

The *Mylor Slates* in this district support a soil inferior to the other sedimentary divisions. This is largely due to the fact that it flanks the granite, the marginal portion of that mass and the adjoining slates being the metal-producing zone, so that it has been extensively veined by quartz. The quartz *débris* scattered over the ground is sometimes so great that the surface soil consists of little else, and the land is out of cultivation, while in other districts the agricultural land is considerably impoverished from this cause. Where these conditions, however, do not prevail, the soil is little inferior to that of the Portscatho or Falmouth divisions. This division has a tendency to form uplands with shallower valleys than are found in the Portscatho series.

## 3. South Wales District.—Glamorganshire and Carmarthenshire.

Mr. Aubrey Strahan, District Geologist.

Mr. R. H. Tiddeman
Mr. B. S. N. Wilkinson
Mr. T. C. Cantrill
Mr. H. H. Thomas
} Geologists.

### Ordovician Rocks.

Mr. Strahan. The surveying of Sheet 230, which includes the North Crop of the coalfield from Ystradgynlais to Mynydd Mawr, has necessitated the mapping of some of the older rocks near Llandilo. The Ordovician Rocks enter the sheet with a strike of W. 30° S., which, however, curves westwards to nearly east and west. The movement to which this strike is due has been so energetic as not only to place the strata of a broad belt of ground in a vertical position, but to give rise to over-folding and over-thrusting. All the rocks up to the Coal Measures are involved, but the effects of the movement are manifested chiefly in the older rocks, and to a

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less degree in the Carboniferous areas, though it has sufficed to tilt the limestone and Millstone Grit at an angle of 45°, and to plicate the Coal Measures near Llandybie. Mr. Strahan.

Proof has been obtained of the existence of movements of more than one age, but the dominant, and perhaps the most recent, has been that to which the present strike is due. By its direction this disturbance links itself on to those of Cribarth and the Vale of Neath. These well-marked belts of compression range about W. 30° S., and succeed one another at fairly regular intervals. Thus the Vale of Neath disturbance is followed, after an interval of seven miles, by the Cribarth disturbance. Cribarth is followed, at seven miles distance, by the Tair Carn anticline, and that anticline, both by direction and situation, is connected with the upheaved belt of Ordovician and Silurian rocks.

Of the age of this system of movements we have no direct proof, but the work has shown that it was probably not contemporaneous with the pre-Triassic east and west folds of the South Crop. Neither the Vale of Neath nor the Cribarth disturbances link themselves on to that system, either in character or direction.

It has been observed, by both Mr. Cantrill and Mr. Thomas, that the dip of the Silurian rocks is generally steeper than that of the Ordovician. Both dip to the south, but the Silurian at 70° to 80°, while the older rock dips at 45° to 60° only. If the junction were an unconformity and not faulted, this could only be accounted for on the supposition that the Ordovician strata had had a northerly dip before the Silurian rocks were deposited; but the evidence for a great fracture is so convincing that we may adopt the explanation that the difference in inclination is due to two portions of a great **S**-shaped (sigmoidal) curve having been faulted into juxtaposition. Thus the Ordovician rocks have the angle of dip proper to the upper limb of the **S**; while the Silurian rocks have the steeper dip which prevails in the central limb.

The district is traversed also by some clean-cut normal faults of the N.N.W. direction. A good example of such a fault has been traced by Mr. Thomas from Bryn Martin Uchaf to the Keeper's Lodge at Llanfihangel, the shift of outcrop being as much as 100 to 150 yards in highly-inclined beds; but no case has been found of a N.N.W. fault traversing the whole of the belt of disturbance referred to above. The results of the detailed mapping are recorded by Mr. Cantrill as follows:—

The Ordovician rocks are excellently exposed in the sides of the River Cennen and in a railway cutting at Ffairfach. They show the following sub-divisions in descending order:— Mr. Cantrill.

| | | |
|---|---|---|
| 3. | Flags and Limestones | Llandilo Beds. |
| 2. | Ffairfach Grit | |
| 1. | *Didymograptus*-Shales. | Llanvirn Beds (?) |



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Mr. Cantrill and Mr. Thomas.

1. The *Didymograptus*-Shales* are somewhat micaceous black shales and mudstones, containing numerous *Didymograptidæ* with a few *Lingulæ* and trilobites. Their base is nowhere seen, but the shales are probably at least 300 to 400 feet thick. They pass up into a more sandy and micaceous rock with few or no fossils. In carrying on the work westwards Mr. Thomas estimates that the unfossiliferous micaceous part of the shales is 150 feet thick, and that the graptolitic shales are exposed to a thickness of probably more than 200 feet. He finds *Didymograptus bifidus* to be the commonest form, but the classification of the beds will depend upon further identifications.

2. The Ffairfach Grit is described by Mr. Cantrill as a hard, yellowish sandstone, grey and calcareous when unweathered, and about 150 feet thick. It is found by Mr. Thomas to pass in places into a sandy limestone, apparently unfossiliferous. It is well exposed in the Ffairfach cutting and under the terrace of Golden Grove House.

3. The Flags and Limestones of the Llandilo group, as shown in the Ffairfach cutting, consist of about 150 feet of thin-bedded, dark grey sandy mudstones, overlain by 150 feet of pebbly, soft sandstones, above which, again, come dark flags and limestones, often weathered into rottenstones. The outcrop in the Cennen Valley is found by Mr. Cantrill to be two-thirds of a mile broad, which, with a dip ranging from 40° to 70°, indicates an *apparent* thickness of about 2,500 feet. The top of the flags is not seen. In reference to these rocks farther west, Mr. Thomas writes that the limestones cannot be traced far, owing to their habit of weathering into rottenstone, but that they are not so sporadic as would appear at first sight. A large mass occurs in an old quarry in Golden Grove Park. He finds in the flags and limestones an abundance of fossils, chiefly trilobites and brachiopods. Here, also, proof is obtained of a great gap between the highest seen Ordovician and the Silurian rocks, the upper Llandilo being absent in Mr. Thomas's opinion, as well as the Bala and Llandovery series.

## SILURIAN ROCKS.

### *Llandilo.*

Mr. Cantrill.

The development of hard red and grey pebbly grits (Passage Beds) forms one of the most conspicuous features in the highest Silurian rocks near and east of Llandilo. These strata form a well-marked ridge extending from Trichrug, where they are well developed, westwards towards Storm Hill, but farther west they disappear, partly through an unconformable overlap by the Old Red Sandstone, but not less by gradual attenuation in themselves. In the eastern part of their range, at Cilmaenllwyd, Mr. Cantrill finds the following descending succession:—

* This name was introduced by Messrs. Marr and Roberts. *Quart. Journ. Geol. Soc.*, vol. xli., p. 476 (1885).

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Old Red Sandstone: red micaceous marls, containing *Lingulæ* for about five or six feet above their base, passing down into Mr. Cantrill.

| | | Ft. |
|---|---|---|
| Passage Beds. | Tilestones: yellow, highly micaceous sandstones formerly wrought for tiles; fossiliferous; about | 150 |
| | Trichrug Beds: red sandstones and grits and sandy marls, mostly pebbly; passing down into yellow grits at their base | 600 |
| | *Grammysia*-beds: dark purplish-grey, flaggy sandstones, with thin seams crowded with fossils, among which *Grammysia* is very abundant; about | 180 |
| Ludlow and Wenlock. | Greenish-buff mudstones, with thin harder seams, and below them several bands of hard yellow sandstone, one about 150 feet thick, for which the name of Lletty Grit will be convenient | 2000 |
| | Greenish-grey mudstones | |

The last-named may be assigned to the Wenlock group. In carrying on the account westwards, Mr. Thomas observes that both the Tilestones and Trichrug Beds have disappeared near Golden Grove Park, leaving the Old Red Sandstone in direct superposition upon Ludlow mudstones. In the same neighbourhood the base of the newer formation becomes conglomeratic and contains angular fragments of the underlying mudstone. Between the Ludlow and Wenlock he finds that no hard-and-fast line can be drawn. The Lletty Grit, one of the most constant of several grits which make their appearance in the middle and upper parts of the Silurian mudstones, is about 180 feet thick, and can be traced on. Sandstones are, on the whole, thicker and more abundant in the upper than in the lower part of the mudstones. Fossils abound along certain lines, not, however, in the grits. Amongst others he has obtained *Calymene Blumenbachii*, *Phacops caudatus* and other trilobites, with *Atrypa reticulata*, *Leptæna rhomboidea*, *Cyrtia exporrecta*, etc. Mr. Thomas

With respect to the junction of the Silurian and Ordovician rocks near Golden Grove, Mr. Thomas makes the following note:—

The lowest Silurian rocks are greenish-brown or buff mudstones, with thin bands of sandstone. These are of Wenlock age. They rest sometimes against Llandilo flags, sometimes against the Ffairfach Grit, and sometimes against the *Didymograptus* shales. The junction is therefore either an unconformity of great magnitude, or a fault. But though it is exposed in four places, the base of the Silurian rocks contains no trace of conglomerate such as might have been expected in the case of a great unconformity. On the other hand, there are indications that the Silurian mudstones have been indurated near the junction, and that in both them and the Ordovician a cleavage has been developed, with traces of foliation along bedding-planes. At the back of Golden Grove the junction is laid bare by a stream for 250 yards, and here it is actually seen to be a fault, accompanied by much crushing on both sides, and signs of shearing in the neighbouring beds. The

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Mr. Thomas. evidence points to its being a fault in all other parts also of the district mapped. The conclusion is in accord with Mr. Cantrill's observations. At an exposure of the junction at Troedyrhiw he finds that the Silurian rocks dip at an angle of 40° *towards* vertical Llandilo beds, and concludes, both from this and the absence of conglomerate, that the junction is a large fault, or perhaps a thrust.

### *Gower.*

Mr. Strahan. Two inliers of Silurian rocks have been found this year in Gower. They had escaped notice in the original survey of South Wales, and were not known to exist until they were detected by Mr. Tiddeman. The larger of the two forms an undulating table-land on the north side of the ridge known as Cefn-y-Bryn. The Old Red Sandstone composing the ridge dips southwards, and from beneath it emerge soft, olive-coloured shales, the junction between the two being sharply defined. The inlier, though two and a half miles long, is narrow, being bounded on the north by a fault which throws down various members of the Old Red Sandstone and the Lower Limestone Shales in succession.

Mr. Tiddeman. The smaller inlier lies north-west of Penmaen Workhouse. On its east side it is bounded by a fault which crosses the anticline of Cefn-y-Bryn obliquely; but towards the south-west it is succeeded naturally by Old Red Sandstone. The shales are poorly exposed, but Mr. Tiddeman obtained fossils, which were identified by Mr. Newton as:—*Rhynchonella* (like *R. nucula*), *Bellerophon* (like *B. Murchisoni*), *Modiolopsis ?*, *Chonetes* sp., crinoid ossicles, entomostraca.

## OLD RED SANDSTONE.

### *North Crop.*

Mr. Cantrill. The mapping of the Old Red Sandstone on the north side of the Coalfield has been continued by Messrs. Cantrill and Thomas. With respect to the neighbourhood of Derwydd Road and Trapp, Mr. Cantrill writes that the lowest subdivision, or red marls, is exposed in the Cennen, but that none of the conglomeratic cornstones, so frequent near Gwynfe and eastwards, are present. At Cilmaenllwyd the lowest few feet are highly micaceous and contain a few small *Lingulæ*, survivors, possibly, of the Silurian fauna. Traced westwards, the basement-beds become more sandy and assume a pale-green and yellow colour. No hard-and-fast line could be drawn between these and the Tilestones of the Silurian Passage Beds, the one seeming to pass into the other. This is especially noticeable in an excellent section on the main road to Llanelly, on the west side of the Cennen Valley.

Mr. Thomas. Still farther west, however, the succession is changed. As noticed above, Mr. Thomas finds a marked overlap of the Silurian rocks by the Old Red Sandstone, accompanied by the development

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of conglomerate in the base of the newer formation. A green tinge prevails at the base of the Old Red Sandstone, and one of the lowest beds is a fissile green sandstone, which has been worked as a tilestone, but which must not be confounded with the Tilestones of the Silurian Passage Beds. Mr. Thomas.

The series of green and dull-red sandstones, to which Mr. Cantrill gives the name of Senni Beds, forms the lower part of the Brownstones, and has been traced continuously so far as the surveying has proceeded. The great mass of the Brownstones above repeatedly yields exposures, but whereas in the Carmarthen Fans the beds consist of innumerable alternations of sandstone with marl, farther west marls form the bulk of the subdivision. The quartz-conglomerates, also, which form the scarps of the Carmarthen Fans persist no farther west than the Clydach Valley. It thus happens that the Grey Grits, or uppermost subdivision of the Old Red Sandstone, there rest upon marls Mr. Cantrill.

A little farther west, however, the Grey Grits disappear, but to the south of Trapp an olive-green sandstone with quartz-pebbles comes in at a probably lower horizon below the Lower Limestone Shales. At Llandyfan, where the rock is about 20 feet thick, and contains rolled flakes of dark shale, it is separated from the Limestone Shales by 150 feet of coarse red sandstone and red marls. North of Llandybie the upper beds of the Brownstones tend to become still more sandy, as is well shown at Cilyrychen Quarry, where the Lower Limestone Shales, with a few feet of dark green sandstone at their base, rest upon green, red and brown sandstones and marls with conglomeratic cornstones containing fossiliferous pebbles.

The disappearance of the Grey Grits has been traced by Mr. Cantrill step by step from the Carmarthen Fans, by the head of the Cennen, where they are pebbly and 15 feet thick, to Banc Wern Wgan, where they are devoid of pebbles and only 8 feet thick. Farther west they are represented by only about 6 feet of greenish-brown grit, separated from the Lower Limestone Shales by a few feet of red marls; but no obvious representative of the Grey Grits has been recognised west of Cwrt Bryn-y-Beirdd.

### *Gower.*

In Gower the Old Red Sandstone has been found by Messrs. Tiddeman and Wilkinson to occur in the form of sharp anticlinal folds, running approximately east and west. In nearly every case, however, one limb of the anticline is replaced by a fault. The following subdivisions are recognised:— Messrs. Strahan, Tiddeman, and Wilkinson.

White quartz-grit (the Grey Grits), freely charged with pebbles of vein-quartz.
Red ditto ditto
Red and purple sandstones (the Brownstones).
Red and purple marls, with an occasional conglomeratic cornstone.

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Messrs. Strahan, Tiddeman, and Wilkinson.

The last named are not often visible, and may be absent on Cefn-y-Bryn. The red sandstones, which are usually conspicuous, graduate up into the red conglomerate, but there is a fairly well-marked boundary between the red and white conglomerates. In one case noted by Mr. Tiddeman pebbles and fragments of hæmatite occur in the Old Red conglomerate.

The detection of Ludlow Beds in the Cefn-y-Bryn anticline has changed our views with respect to the development of the Old Red Sandstone. From a rough estimate the thickness of the latter formation in Cefn-y-Bryn can scarcely exceed 400 feet, though it amounts to 3,500 feet near Cardiff and to still more in the Brecknock outcrop. Moreover, in Rhossili Hill there are beds represented which are absent in Cefn-y-Bryn, and a greater thickness of the Brownstones and marls exposed, without reaching the base. The attenuation of the Old Red Sandstone in Cefn-y-Bryn takes place chiefly in the lowest subdivision, the marls with cornstones, which, indeed, are doubtfully represented by a few feet only; but the Brownstones also, though certainly present, are greatly diminished. The uppermost conglomeratic subdivisions, on the other hand, are well developed. It is clear therefore that the diminished thickness of the Old Red Sandstone is not due either to an overlap by the Carboniferous shales, or to an overlap of the Brownstones by the conglomerates, or apparently to an overlap of the marls by the Brownstones, but to attenuation in the two last-named. These facts suggest an unconformity between the red rocks and the Ludlow shales—a matter which will receive further investigation.

## CARBONIFEROUS LIMESTONE.

### *North Crop.*

Mr. Cantrill.

In the North Crop Mr. Cantrill makes the following observations on the Carboniferous Limestone. It presents, in descending succession:—

Rottenstone Series.—Fine-grained, white and yellow sandstone with rotten chert-bands in the upper and rottenstones in the lower part.

Main Limestone 600 to 700 ft.
- Dark limestones with black chert-nodules.
- Light-grey oolite about 50 feet thick; at its base about 15 feet of soft sandstone.
- Dark limestone and oolite. *Lithostrotion irregulare* at base.

Lower Limestone Shales.—About 40 or 50 feet, but tending to thin westwards.

The Rottenstone Series has been exceptionally well exposed in the Bynea Brick Company's "plastic clay" level at Garnbica. There the beds between the Millstone Grit and the top of the main limestone are about 60 feet thick. They consist of yellow sandy material in beds about six inches in thickness, some of which have the flinty and angular fracture, and occasionally the nodular form, of chert, while a very few contain a small core of

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undecomposed chert. A band of black clay 1½ feet thick, near the middle of the series, may be a decalcified limestone, and at the bottom there is a rottenstone, 12 feet thick, which, however, is too clayey for commercial purposes. The "plastic clay," for which the level is worked, appears to be an impalpably fine "silica-sand." It occurs in thin bands among the harder and coarser material. Mr. Cantrill.

*Gower.*

Notice has been previously made of some pitted and nodular limestones, which had been observed by Mr. Tiddeman in the upper part of the Carboniferous Limestone at Newton Nottage and in Gower.* He now makes the further observation on these rocks that they are almost always associated with thin coaly beds containing carbonised vegetable matter, such bands having been noted by him at Newton Nottage, Oystermouth, Mumbles, Pwll-du Head, Oxwich Head, Bishopston, Ilston, Llethrid and Llanrhidian. From a smut-bed of this character at Oxwich Head he has obtained a number of small gasteropoda, which may prove to be new to Carboniferous rocks. The section is given by him as follows, in descending order:— Mr. Tiddeman.

| *Oxwich Point.* | ft. | in. |
|---|---|---|
| Dark crystalline encrinital limestone. | | |
| Black compact limestone, seen to - - - - - | 20 | 0 |
| Black calcareous mud with bryozoa - - - - - | | 6 |
| Crushed limestone with veins of calcite and *Productus* at top - - - - - - - - - 2 ft. to | 3 | 0 |
| Brown or black muddy bed with gasteropoda and vegetable remains (? fucoids) - - - - - - 1 ft. to | 3 | 0 |
| Irregular limestone with *Lithostrotion* abundant, also *Zaphrentis* and *Euomphalus*, and occasionally *Stigmaria;* base not seen. | | |

The nodular limestone series is quite 200 feet thick at Oxwich Head, and is exposed to a thickness of more than 200 feet at Llanrhidian. Mr. Tiddeman proposes to apply to it the name of Mumbles Head Beds.

With reference to the Rottenstone or Bishopston Beds,† Mr. Tiddeman writes that these strata, "as represented by the 'Black Lias' at Oystermouth and the decalcified limestone at Bishopston, have been traced over a wider area than was assigned to them by De la Beche. It is true that they are thickest at Bishopston, but we also find traces of them on the southern side of the peninsula. Thus the rottenstone occurs in pockets in the Mumbles Head Beds at Pwll-du Head, as well as overlying the same beds at Port Eynon at the old paint-mine and on the foreshore. At the paint-mine the *Spirifer* which abounds at Bishopston was found. Traces of the rottenstone have been detected on the northern margin of the Carboniferous Limestone at Ilston,

* *Summary of Progress* for 1900, p. 87.

† *Summary of Progress* for 1900, pp. 87, 88.

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Mr. Tiddeman. Llethrid, near Cae Morgan, and Cil Ifor. At both the last-named localities *Wavellite* occurred, and they are probably the places hinted at by De la Beche where Logan found this mineral."*

### MILLSTONE GRIT.

#### *Gower.*

The Rottenstone Beds are followed upwards by Millstone Grit, which consists chiefly of black shales, but at a distance from the limestone corresponding to a thickness of 100 to 300 feet, Mr. Tiddeman finds a fairly persistent bed of compact, almost cherty, sandstone, which breaks up into cubes or rhombs; this band is to be seen at intervals from Bishopston to Llanrhidian. A higher horizon of sandstone bedded with blue and black shale runs parallel with it from Pengwern Farm through the south end of Cillibion Plantation and by Parc-y-rhedyn, but not east from Bishopston. A third still higher sandstone runs through the north end of Cil Ifor Top, though not through the highest point of the hill. This rock has been quarried for building, and certain beds in it serve as freestones. The succession generally presents but little resemblance to that of the North Crop.

#### *North Crop.*

Mr. Cantrill. The main subdivisions of the Millstone Grit have been mapped by Mr. Cantrill through the area surveyed this year, but in a slightly modified form. The quartz-pebbles in the basement-grit become scarcer westwards and almost disappear near Careg Dwfan. At the same time bands of shale tend to come in near the base, and Mr. Cantrill thinks it possible that the radiolarian cherts† may be found in a black shale some 10 feet above the base of the grit.

Such a bed of shale has been exposed near the Garn-bica Level. It is 16 feet thick and contains lamellibranchs resembling *Posidonomya*, ostracoda, and plant remains; there occur also beds which look like rottenstones and decomposed chert, but between it and the Rottenstone Beds proper there are some few feet of quartz-grit. Similar shale-bands occur elsewhere, so that there would appear to be an alternating passage up from the Limestone into the Millstone Grit.

The middle or shaly subdivision of the Millstone Grit passes down into the underlying grits. The Farewell Rock or uppermost subdivision runs, as a thin band of olive-brown sandstone, south-westwards of Llandyfan and west of Llandybie.

### COAL MEASURES.

The past year's work in the Coal Measures has lain in the North Crop between Glanamman and Llandybie, and in the South Crop between Swansea and Llanelly, including the north side of Gower.

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**Mem. Geol. Survey*, vol. i., p. 134.

†Described in the *Summary of Progress* for 1900, pp 88, 89.

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*North Crop.*

Mr. Cantrill.

In attempting to locate the base of the Coal Measures along the north side of the Amman Valley, between Glanamman and Ammanford, much difficulty has been encountered through the prevalence of Boulder Clay, the existence of obscure east and west rolls connected with the Tair Carn anticline, and the occurrence of several faults belonging to the N.N.W. system.

The lowest or Astell vein, which at Brynamman serves as a base to the Coal Measures, is represented possibly by a small vein which crops out at Bryn Pedol. Its outcrop probably passes through Cynghordy and Glyndreiniog to Tyllwyd, where it is thrown northwards by the Nant-main or Tyllwyd Fault—a large downthrow west. West of this fault, however, the base of the Coal Measures is conjectural; the lowest veins known being the group formerly worked at Tyllwyd and Brynlloi, which comprises probably the Little Brass, Middle and Lower Veins of Brynamman. Some little exploration has been made upon these, also a little south of Garenig Bridge, but west of the Cwm Garenig Fault their position is unknown; they are presumably thrown northwards and probably crop out under the Boulder Clay on the north side of the Amman. The parallel fault of Glyn Moch, which runs 500 yards farther west and is also a downthrow west, must throw them still farther north, for the Big and Brass Veins crop under the Boulder Clay between Ynys-y-fawnen and Aber-nant, where they were worked at the Llwyn yr hâf Shaft and Drift. West of this point all workings between the Amman and the axial line of the Tair Carn anticline cease. Some veins which are probably low in the Coal Measures crop out and were formerly worked by openworks between Glynhir and Drefach; but their correlation remains doubtful. The same veins should rise again to the north near Llandyfan, but the ground is unproved as far west as the Dinas Fault, near Llandybie. Beyond the fault the lowest veins are known as the Piodau veins.

In the Amman Valley the various ironstones and coals—from the Big down to the Brynlloi—which were extensively worked at Glanamman are cut off by the Cwm Garenig Fault, and except at Llwyn yr hâf are unknown between this fault and the Bettws Fault; the old cropworks at Pontamman and the veins at present worked in the Ammanford Colliery not having yet been satisfactorily correlated.

The Red Vein formerly worked at the old Cawdor Colliery in Cwm Garenig is there thrown down on the west by the Cwm Garenig Fault into the Amman Valley; and again further west by the Glyn Moch Fault. It was formerly worked at Glyn Moch Colliery, and the crop can be traced easily thence as far as the Bettws Fault. At the Red Vein workings of the Ammanford Colliery Co. a clod five feet thick comes in in the middle of the coal and persists westwards.

Several thin veins above the Red Vein have been worked along the crops on the high ground south of the Amman Valley.

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Mr Cantrill. One of these, known as the Butcher's Vein, has been traced from the Cwm Garenig Fault, past Waun-hir and the Butcher's Arms, into Cwm Cathan, where it is probably the Garn Swllt Vein. This may prove to be the representative of the Ynysarwed or No. 2 Rhondda Vein.

*South Crop and Gower.*

Mr. Strahan. Field work during 1901 was carried on by Mr. Strahan in the Coal Measures between Loughor and Llanelly and in the northern part of Gower. The inclination of the measures of the South Crop is always high, but in Gower, not far from the western end of the Coal basin, it approaches verticality, and is accompanied by a number of extremely sharp folds. The steepest dips and the folding occur along the outcrop of the lowest measures, which are almost wholly composed of shale; northwards the inclination steadily diminishes, and the massive sandstones which accompany the Dunvant Veins are not only free from folding but form a regular outcrop, interrupted only by the north and south faults. Still farther to the north, after passing a depression due to the outcrop of the Penlan Vein and some soft measures associated with it, we reach the dominant feature of the district, an almost continuous range of hills formed by the Pennant Series.

The Pennant Series, however, of this part of the coalfield differs from that of Monmouthshire in the fact that its upper part includes several valuable seams of coal and thick beds of shale. Thus the Hughes group of coals lies about 500 yards below the Four-Feet Vein, which we take as the top of the series, and crops out along a continuous strike-valley which runs from Swansea to near Penclawdd. Northwards this valley is dominated by a subordinate range of sandstone-hills, on which Wig-fawr and Allt-wen are situated, and this again is succeeded by a northward slope in which the Two-Feet, Three-Feet and Six-Feet Veins crop out, together with some subordinate sandstones. Finally at the edge of the low ground we reach the outcrop of the Four-Feet Vein and the top of those productive measures which we believe to correspond to the unproductive upper part of the Pennant of Monmouthshire.

Thus far the dip has been uniformly to the north, but at an always diminishing angle. The beds at length become horizontal under the alluvial flat north of Gowerton, and then gently rise to form a low anticline which runs through Mynydd Carn-goch, Loughor Upper Town, and south of Broadoak Colliery. The form of the ground, however, corresponds to the dip of the strata, so that the Four-Feet Vein keeps near the surface, without actually cropping out. This Broadoak anticline is followed northwards by a shallow syncline which runs north-westwards under Loughor Common, as proved in old workings in the Four-Feet Vein. The tract lying north of the syncline has not yet been proved. The measures strike due north and south for about two miles and include a group of three seams known as the Grovesend Veins besides one or more thin seams above.

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There is much doubt whether the Grovesend Veins are equivalent to the seams which crop out at Melin Llan* and Gelligynore, and, therefore, represent the Four-Feet Seam, or whether they lie above them. The Drift of the Mountain Colliery was commenced in the outcrop of one of the Grovesend Veins and then passed through an upthrow fault into the Four-Feet Vein, which was extensively worked and found to differ in section from any of the Grovesend group. This would seem to prove that the Grovesend group lies above the Four-Feet, but how far above is not known, the throw of the fault never having been proved. On the other hand the Grovesend Veins are said not to match any of the known seams which lie above the Four-Feet in the neighbourhood. A shaft in progress at Cefn-Arda has not thrown any light on the matter so far, for it was commenced a few yards below the Grovesend crop and has been sunk over 250 yards without proving any recognisable seam. If the Grovesend seams correspond to the Four-Feet Vein and Rider, the Five-Feet should have been found in this shaft at about 120 yards depth, and the Six-Feet at about 250 yards depth. Yet if they lie above the Four-Feet, they can hardly be so high above it as the Cefn-Arda shaft seems to indicate, for it would imply that the fault traversed at the Great Mountain Colliery had a throw of not less than 200 yards, in which case it should be traceable both to the north and south of the doubtful region. Mr. Strahan.

Two seams occur above the Four-Feet near Loughor, namely the Loughor Little Vein, 41 yards above it, and the Penyscallen 20½ yards above the Little Vein; a third which is not known to exist near Loughor has been worked to the west of the Loughor Vein under the name of the Gelli Vein; this lies 188 yards above the Four-Feet, and, therefore, corresponds in position to the Drews Vein of Llansamlet and the Bryncoch Vein of the Neath trough. This is the highest vein known in the South Wales Coalfield; it occupies an area of less than a square mile in extent on the east or downthrow side of the Bryn-serfyll Fault.

The sequence of the veins in the Llanelly district corresponds well with that of the Swansea district, but the names are different. A correct correlation is important in estimating the number of seams, if any, that are likely to exist in the Llanelly district beyond those which have been already proved. The accompanying table gives the correlation and the synonyms so far down in the series as the surveying of the district has proceeded. It should be especially noted that the Four-Feet Vein of Swansea becomes the Big Vein of Box and St. David's Collieries, and that the Four-Feet Vein of those Collieries is the Five-Feet Vein of Swansea.

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* *Summary of Progress* for 1900, p. 99.

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## Comparative Table of the Seams above the Hughes Vein between Llanelly and Neath.

(Distances between seams are given in yards.)

| Llanelly District. | | | Loughor. | Swansea District. | Neath District. |
|---|---|---|---|---|---|
| Old Castle Colliery. | St. David's Colliery. | Cae Colliery. | Broadoak Colliery. | —— | —— |
| | Gelli Vein<br>119½<br>Coal, 1 ft. 10 in.<br>11½<br>Coal, 1 ft. 3 in.<br>56<br>188 | | | Drew's Vein<br>135 to 180 | Bryn Coch Vein<br>152 |
| | Box Big Vein<br>98½ | Clement's Vein<br>39<br>Glyngwernen, or Box Big Vein<br>83 | Penyscallen Vein<br>20½<br>Loughor Little Vein<br>41<br>Broadoak Vein<br>96 | Four Feet Vein<br>118 | Wernfraith Vein<br>105 to 110 |
| | Four Feet Vein<br>64½ | Box Five Feet Vein<br>69½ | Five Feet Vein | Five Feet Vein<br>76 to 87 | Greenway or Court Herbert Vein<br>115 to 130 |
| Rosy Vein<br>18 | Rosy Vein<br>24 | Rosy Vein<br>25½ | | Jenkin or Morris Vein<br>44 to 54 | Tir Edmond Vein<br>25 |
| Fiery Vein<br>36 | Fiery Vein | Fiery Vein<br>44 | | Six Feet Vein<br>12 to 20 | Graigola Vein<br>about 25 |
| Golden Vein<br>34 | | Golden Vein | | Three Feet Vein<br>38 to 49 | Upper Maesmelyn Vein<br>53 |
| Bushy Vein | | | | Two Feet Vein | Lower Maesmelyn Vein |

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Returning to the seams in and below the Pennant Series we find that the Hughes Vein has been extensively worked from Swansea to the shores of the Loughor Estuary, though the other veins which belong to the Hughes Group have been touched here and there only. The mass of Pennant rock, which lies below the Hughes Group, contains the Cuckoo Vein, which has been proved near Cockett, but seems to be of secondary importance. At the base of this rock the Penlan Vein has been worked at intervals from near Dunvant to Penclawdd. Eastwards it runs near Hendre-foilan, but is then lost to view under the great mass of gravel of Sketty and Swansea; there is reason to believe, however, that it corresponds with the Dyvatty Vein,* and is therefore, the nearest equivalent we can find to the Rhondda No. 2 Seam. Mr. Strahan.

The Penlan Vein forms the highest of what are known as the Dunvant Veins. Of these the most persistent are, in descending order, the Penclawdd Big Vein (the most important), the Glammant and the Gleilyd, while a fifth, known as the Rock Vein, exists westward only of Dunvant. The Dunvant group is associated with massive sandstones, the Penclawdd Vein especially having so strong a rock above and below that it crops out along the top of a strike-hill and not along the bottom of a strike-valley as was the case with the Hughes and others. These massive sandstones no doubt correspond to the Llynfi rock,† which is associated further east with the Tormynydd Vein.

The Dunvant Veins crop out close to the station of that name and run thence to the sea near Penclawdd, their position being marked by numerous old, as well as recent, crop-workings. Their position under the gravel of Sketty and Swansea has never been ascertained, nor indeed in any part of Swansea Bay except in the shore of Baglan Bay.

From the Dunvant rocks downwards the Coal Measures consist chiefly of shale—a fact which has contributed to the plication, and which renders the unravelling of the structure extremely difficult. One well-marked group of seams traverses the whole peninsula from Clyne to Glan-Morlais; it includes the following seams in descending order:—The Frog Lane, the Big or Six-Feet, the Yankee, the Four-Feet and the Three-Feet, the thickness of measures between the Frog Lane and Three-Feet Veins amounting to 119 yards. The coals of the Glan-Morlais group are highly bituminous, and are now worked at and east of Glan-Morlais. In Clyne Wood where they were worked a few years ago they are said to have been too soft to be of much value.

The sharp folding which has been alluded to as occurring in the lower measures affects the Glan-Morlais group. Though the outcrops are regular from Glan-Morlais for about a mile, they become untraceable near Pen-llwyn-Robert, and the reason is apparent in the workings of the Morlais Vale Colliery, where the veins have been thrown into a series of steep east and west folds. Similar folding is seen between Killay and Mumbles Road Stations.

* *Summary of Progress* for 1900, pp. 93, 94.

† *Summary of Progress* for 1900, p. 94.

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Mr. Strahan. Some distance below the Glan-Morlais group we come to the Farm Vein which has been worked north and north-west of Wern-ffrwd, and is said to be 3 feet 6 inches thick; and the Lynch Rider and Lynch Vein, which is said to be 2 feet 6 inches thick. These were worked a few years ago at Wern-ffrwd, and westward from that place the outcrops are marked by continuous old workings for about a mile, the dip being always high and sometimes reaching verticality. These veins are not continuously traceable across the peninsula, for the strata are intensely squeezed and the outcrops have not the regularity which characterise those of the Pennant Measures. In some places, as happens with the Farm and Lynch Veins near Rallt, two outcrops approach so closely that it is evident that many strata have been squeezed out. Compensation is found close by where the outcrops diverge to more than their normal distance, the extra intervening space in such a case being filled up by plications.

The Lynch Vein is the lowest known seam in Gower. It is succeeded downwards by thick shales with an occasional bed of sandstone, but it is not till we have travelled 500 yards south from the Lynch Vein that we see any noteworthy outcrops of the harder rock. These form a long strike ridge on which Llan-Elen stands, and run along the northern margin of Clyne Common to near Clyne Castle. They have shared, however, in the plication, and both in Clyne Park and along the valley north of it they have been doubled up into a series of sharp synclines and anticlines, a fact which combined with the scarcity of sections makes it impossible to trace their outcrop across the peninsula with precision. These sandstones we take as the top of the Millstone Grit, but it should be understood that the separation of the Coal Measures from the Millstone Grit is purely arbitrary. It is founded neither on palæontological evidence nor on any marked lithological distinction, but is adopted to bring the sequence in Gower into accordance with the sequence elsewhere. That the grits of the Millstone Grit are represented by the shales in Gower is certain; but by how much of them is doubtful. The Llan-Elen sandstones form a convenient horizon for mapping purposes, and not improbably represent the Farewell Rock of other regions.

The coals of the region described above are all bituminous, though the measures, from the Penlan Vein downwards, correspond to the measures of the North Crop, in which all the seams are anthracitic.

A number of normal north and south faults cut across the east and west folds of Gower. They can rarely be traced far, though locally their throw may be large. The Dunvant Fault, for example, though large at Dunvant, is non-existent at Bishwell, though it may turn westwards and join the Alltwen Fault. Several faults have been proved in the Penclawdd Vein near Killan-fawr, the largest being a downthrow west of 99 yards. These faults break through the crop of the Hughes Vein also, and one of them has been proved in the Four-Feet, but it is questionable

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whether they can be identified near Loughor. In that neighbourhood three faults are known to exist; one was crossed in the Mountain Colliery referred to above; a second was proved in the Pengrys Pit, and is estimated to be a downthrow west, of 120 yards, from a consideration of the difference of level of the Four-Feet Vein at Broad Oak and Loughor Upper Town; the third is a downthrow east, reputed to amount to 200 yards, which has been touched under the estuary of the Loughor above Loughor Bridge. This is approximately in line with a fault which cuts all the outcrops from the Hughes to the Gleilyd near Berth Llwyd in Gower, but which is a downthrow west. Of others mention may be made of a fault of 120 yards downthrow west, which has been traced from the Penlan Vein at Trinity Church in Penclawdd to the Big Vein near Glan-Morlais Station. In the Llanelly District the principal north and south faults are the Bryn-Serfyll and the Box Bar Fault, both large downthrows to the east. Mr. Strahan.

TRIAS.

The occurrence of Triassic outliers in Gower has long been anticipated,* but not proved until the past year. The anticipation was founded on the existence of a high level plane apparently of marine denudation, sufficiently obvious to the eye when on a level with it, but especially significant when it is realised that it is composed of highly inclined strata of widely different hardness. Many of the veins, moreover, in the limestone had served as conduits for a red stain, while some contained hæmatite, strong evidence of the former existence of Trias not far overhead. Two occurrences of Trias may now be recorded. At Port Eynon an excavation from which shale was raised for the manufacture of paint has disclosed the edge of a massive Triassic conglomerate, which is described by Mr. Wilkinson as follows:—"The conglomerate rests upon almost vertical black shales belonging to the Bishopston Series and lower part of the Millstone Grit. The matrix is pinkish, and in places of a soft clayey nature; the boulders, which are large and abundant, have been derived chiefly from the Carboniferous Limestone, but include many of black and grey chert, derived no doubt from the shales above the limestone."

The other locality referred to lies some distance farther west. The Trias occurs in a swallow-hole or chasm in the limestone, due to collapse along a line of fault. The rock is a deep-red sandy marl, variegated with spots and streaks of green. In it are imbedded masses of limestone and calcspar fallen from the walls of the chasm, which obviously was open and undergoing enlargement in Triassic times. A somewhat similar case was recorded in the *Summary of Progress* for 1898, p. 134.

RAISED BEACH.

The sequence of deposits associated with the Raised Beach of Gower was described in the *Summary of Progress* for 1899, pp. 154, 155. During the past year the same sequence has been

* See Tawney, *Proc. Bristol Nat. Soc.*, Ser. 2, vol. i, p. 165.



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Mr. Strahan. observed by Mr. Wilkinson on the north coast between Burry Holms and Hills Tor and on the south side of the Worms Head. Here the beach is little below the 50 feet contour, but between Tears Point and Mewslade Bay it is not more than 15 or 20 feet above sea-level, while from Overton Mere to Oxwich Point it lies just above high-water mark.

## GLACIAL.

In an examination of the Glacial phenomena of South Wales, the fact that the Brecknock Beacons formed an ice-parting claimed early attention. Though boulders derived from them are distributed freely over parts of Monmouthshire and Glamorganshire, no rocks from farther north found their way across them. Later on a similar observation was made with respect to the Pennant escarpment which culminates in Carn Mosyn at a height of nearly 2,000 feet. From this also boulders were carried in abundance southwards, though none succeeded in crossing it from the north. The escarpment, together with others, therefore played the part of a subsidiary ice-parting, for it by no means formed the northern limit of glacial action, but merely acted as a local obstacle to the southward movement of the Brecknock ice, at the same time that it gave birth to a small flow of its own. Recent work tends to show that the Brecknock Beacons themselves played a similar part with reference to the glacial system of Wales, though on a larger scale.

The range formed by the Brecknock Beacons, the Carmarthen Fans, and the Black Mountains, diminishes in height westwards, until in the region now under examination the escarpments of Lower Carboniferous Rocks and Old Red Sandstone rarely exceed 600 feet in height, while they are traversed by valleys or cols descending to 400 or 500 feet above the sea, and one valley, followed by the railway, descending to 200 feet. In the same region the valley of the Carmarthen Towy takes its course along the northern side of the range, and at no great distance from it, the bottom of the valley being about 60 or 70 feet above the sea. Notwithstanding this difference in level, Mr. Cantrill has found repeated proof both in the direction of the striæ and in the dispersal of boulders, that the ice mounted the escarpment and passed over it southwards.

The ice which occupied the Towy Valley travelled down that valley westwards as a whole, and the fact that a part was driven across the escarpment southwards can be explained only on the supposition that the valley was filled to overflowing, and that a region in Central Wales, of which the glacial phenomena are as yet unknown, was buried under ice of great thickness.

Mr. Cantrill. The observations upon which these conclusions are founded have been made chiefly by Mr. Cantrill. He reports as follows:—The ice-movement was parallel to the main features with a tendency to swing southwards when approaching a gap in the Tilestone ridge; thus the striæ near Cilmaenllwyd point S. 52° W., but nearer to the gap of the Cennen Valley they change gradually to

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S. 20° W.. Moreover much Silurian detritus occurs in the Boulder Clay which overspreads the outcrop of the Old Red Sandstone in the Cennen Valley, though very few boulders of the Old Red Sandstone can be found on the Silurian outcrop. Lastly, a limestone quarry half-a-mile south of Ffairfach shows the edges of the beds turned towards the south, as though by the passage of ice up the valley. It is clear, therefore, that the main movement was from the north-east, and was due to a great accumulation of ice in Central Wales. Mr. Cantrill.

Evidence of similar movement has been obtained by Mr. Cantrill on the Millstone Grit scarp between the Cennen and Loughor Valley, near Llandybie. Careg-Dwfan, 926 feet in height, has been striated by ice, which crossed it from the north-east, on its way to the Loughor Valley. A flow passed also through the Millstone Grit gap at Llandybie, but was deflected by the local configuration to a direction S. 15° E. The high Pennant scarp, south of the Amman Valley, was over-ridden by ice forced southwards, a fact which explains the occurrence of many Old Red Sandstone and limestone boulders in Cwm Cathan, and of an abundance of fragments of Silurian mudstones in Nant Ffin, at a distance of six or seven miles from the nearest Silurian outcrop.

Mr. Cantrill notes also the occurrence of conspicuous masses of gravels of late glacial age, where the Cennen leaves the strike-valley west of Trapp, and debouches upon the broad north and south valley followed by the railway. These gravels have been derived from the Cennen Valley, but take a moundy form which is not observable in river-terraces formed under existing conditions. They were probably the work of effluents from the ice-sheet, during a late period in its existence. From the fact that they extend southwards, it seems probable that the effluents took that direction, and not the northward course now followed by the Cennen.

To the west of Swansea there is a great development of mounds and ridges of gravel. The deposit covers the whole of the slopes extending from the shore to the foot of the Pennant scarp, nor has its base ever been reached, either in the lower part of Swansea or near Sketty. Clyne river has cut through it to the Coal Measures, and the rock crops out in the fore-shore at Liliput, in both cases near the western limit of the gravel tract. Part of the deposit is a tumultuous assemblage of well-rounded boulders up to 6 or 8 inches in length, imbedded in a gravelly matrix, but the deeper sections usually reveal roughly stratified sand and gravel; in an old brick-pit near Clyne Colliery the gravel is associated with a deposit consisting of alternations of fine sand and laminated loam, such a sediment as would be formed in tranquil water into which sediment was being poured rather copiously. The gravels have been thrown down everywhere in hummocks and ridges, enclosing hollows, and the character of the laminated deposit suggests that it was laid down in one of these hollows; glacial conditions still prevailed, however, for the loam was subsequently buried under a few feet of Boulder Clay. Mr. Strahan.



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Mr. Strahan. The boulders of the Swansea and Sketty gravels include, in order of abundance, Coal Measure grits, white pebbly grits, and Old Red Sandstone. That the material was derived from the North Crop, by way of the Swansea Valley, seems certain, but the source of the pebbly grits is open to doubt. Some much resemble the pebbly Silurian passage-beds, but they have yielded no fossils.

The gravel-ridges generally run parallel to the Pennant escarpment, but a few large hummocks jut out from the hillside in a southerly direction, as, for example, on either side of the valley running down from Cockett to Sketty. Both at Swansea and Llanelly the direction of transport seems to have had a strong westward trend, wherever the local configuration of the ground permitted. The spit of land which projects into the estuary south of Llanelly owes its existence principally to a mound of glacial gravel, and to a shingle-ridge derived from it. A cliff, about 60 feet high, shows a very coarse, roughly stratified gravel with beds of sand, contorted in places. The boulders range up to 2 feet in length and the assemblage resembles that of the Swansea gravel. A bore-hole put down on the eastern slope of the mound is said to have passed through 120 yards of loose material before reaching solid rock. Several other gravel-mounds project through the alluvium between Llanelly and Loughor Bridge, in a tract on which the mining information has not yet been collected.

Striations on rock-in-place are scarce everywhere near the southern margin of glaciation. The southernmost striæ observed during the past year occur in a quarry at Allt, near Llangennech (Sheet 230). They range W. 35° S., and point clearly to the ice having had a more westerly trend than has the Loughor River. None have been found in any part of Gower, though striated boulders are common.

Mr. Tiddeman. A long crescentic ridge, on the top of an east and west hill on Welsh Moor, is described by Mr. Tiddeman as looking like the terminal mark of a glacier or ice-sheet, momentarily advancing during its retreat northwards. The east and west arrangement of mounds of gravel and Boulder Clay, between Killay and Fairwood suggest the same kind of action. But, on the other hand, he considers the gravel-mounds at the confluence of several streams above Bishopston to have more probably been due to the action of glacial streams on the material brought by the ice-sheet. As throwing light on the direction of transport Mr. Wilkinson notes that boulders of Old Red Sandstone are far more numerous on the south than on the north sides of the hills formed by that rock. To this may be added the fact that Coal Measure detritus abounds in the Drift far to the south of the base of that formation.

Mr. Wilkinson.

Mr. Strahan and Mr. Wilkinson. Some of the Drift, and especially the lowest part of it, is of strictly local origin. Thus in the fine section of Rhossili Bay there rests immediately upon the limestone an accumulation composed almost wholly of limestone-fragments, while above this again, with a fairly definite base, comes a mass of gravel in

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which well-rounded far-travelled boulders of Coal Measures, Old Red Sandstone, &c., predominate. Again, in the centre of the bay the cliff is composed of boulders derived from the hill-slope above, but close by, to the north and south, the Drift of more distant origin comes in on top of the purely local material. It is worthy of note that this mass of local Drift lies just opposite a hollow in the hillside. Mr. Strahan and Mr. Wilkinson.

Several large domes of stratified sand and gravel have been noted by Mr. Wilkinson. From the general gravelly character of the Boulder Clay, especially near the surface, there is always much difficulty in separating it from the sand and gravel.

ECONOMICS.

The ground surveyed during the past year is almost wholly pasture, but little more land on each farm being kept under the plough than is necessary for the wants of the farmer. The soil yielded by the Glacial Drift, whether of the type distinguished as "Boulder Clay," or that as "Sand and Gravel," may all be classed as gravelly. There is a considerable area of salt marsh in the estuary of the Loughor which is valuable as pasture, and the gathering of cockles in the tidal sands beyond constitutes an important industry. Parts of the Millstone Grit and Pennant Grit outcrops consist of mountain land, but such tracts are far less extensive than in the central parts of the coalfield. The steeper slopes of the hills are utilised for the growth of pit timber. Mr. Strahan.

Among economic products apart from coal may be mentioned the Carboniferous Limestone burnt at Llandybie and Oystermouth (both white and so called "Black Lias" limestone), and the Llandilo Limestone at Llandilo. Building-stone is obtained chiefly from the Pennant Grit, at Pen-y-Fan, Dunvant, and Cockett; and paving-stone from a quarry between Llanelly and Felin Foel. The Tilestones were formerly quarried for roofing. Clay for puddling is dug on the foreshore at Swansea, and rottenstone is worked to a small extent in the Upper Limestone Shales of the North Crop, but a more important industry consists in the quarrying of the more purely siliceous bands in the Millstone Grit at Carn Bica for the manufacture of fire-bricks at the Bynea Brick Works near Llanelly. "Plastic clay," an impalpably fine siliceous sand, is worked by level near the same place. Millstone Grit shale, stained purple or red by infiltration from Trias, used to be ground up and made into paint near Port Eynon.

## 4. Examination of New Railway and other Sections.

### NOTES ON A NEW RAILWAY IN COURSE OF CONSTRUCTION BETWEEN AXMINSTER AND LYME REGIS.

BY H. B. WOODWARD.

The railway, which is a "light" one, starts from the main line of the London and South-Western Railway a little south-west of Axminster station, and at an elevation of about ninety feet.

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Mr. Woodward.

It follows a serpentine course to Combe Pyne Hill, attaining an elevation of about 415 feet, and after passing through Uplyme, terminates to the north-west of Lyme Regis at an elevation of about 240 feet.

In a shallow cutting by the main line, valley gravel was seen to rest irregularly on the Keuper Marl. The gravel consists for the most part of rough flint and chert stones, with pebbles of quartz and dark grit. Stones occur some way down in the Keuper Marl, having probably descended through cracks formed in dry weather; but here and farther on there are evidences of considerable soil movements and small landslips which have led to the incorporation of gravel with red marl.

Thus by the orchard south-west of Shools Farm there was an interesting section of the valley drift, a good deal disturbed, and showing gravel with patches and bands of red Keuper Marl, which in the re-arranged condition showed little or no variegation. (Fig. 1.)

Below the railway by Abbey Gate Bridge the road-cutting showed pockets of gravel in the red and variegated Keuper Marl,

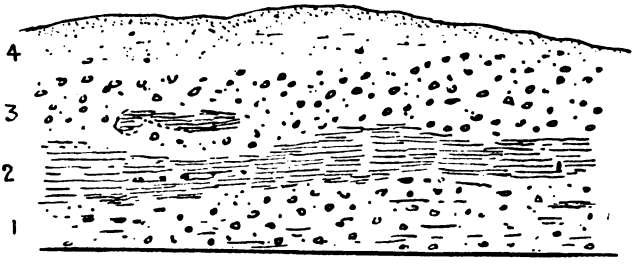


Fig. 1. Section south-west of Shools Farm near Axminster.

4. Soil and sandy loam.
3. Gravel with patch of red marl.
2. Red marl with stones.
1. Clayey gravel.

} 8 to 9 feet.

a feature perhaps due to the effects of subterranean stream erosion.

Southwards a broad patch of gravel extends to near Bean Close Coppice, where grey and greenish marls appear above the red and variegated Keuper Marls, forming the passage-beds into the Rhætic formation.

By the bend of the railway, north-east of Great Trill, a striking section was displayed of inclined and banded red and variegated Keuper Marls with overlying and partially interbedded gravel—an arrangement evidently due to the slipping of a mass of ground, and during the process some slight faults were produced in the Keuper Marls, which have a north-westerly dip. The features occur on the spur of a hill. (Figs. 2 and 3.)

Further south, near South Ground Linhay, there is a cutting in the Keuper Marls, comprising red and variegated marls and a conspicuous band of hard pale marl, overlain by grey, green, and red marls, and higher up by grey marls.

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These strata were hollowed out on the eastern bank of the cutting to a depth of 20 to 25 feet, nearly to the level of the railway, the cutting being about 30 feet deep, and in the hollow was a mass of sand and chert detritus derived from the Upper Greensand. On the western bank, towards the valley, where the cutting is lower (18 to 20 feet deep) there was a wider spread of Greensand *débris*, and the Keuper Marls showed evidence of slight anticlinal disturbance, which may have been due to the breaking away of a mass of Greensand from the uplands of Trinity Hill on the east. (Figs. 4 and 5.) Mr. Woodward.

North side.

South side.

Figs. 2 and 3. Railway-cutting north-east of Great Trill near Axminster.
2. Gravel.
1. Keuper. Red marl with bands of green marl. } Up to 12 feet.

In following the railway towards Newlands Coppice the cutting (in course of construction) showed pale and dark grey marls, with irregular patches of chert detritus. By the Coppice there was a trace of black clay, evidently a portion of the Rhætic (*Avicula-contorta*) Shales, as the soil above contained fragments of White Lias.

To the south-east of Newlands Farm there is a long cutting from 10 to 25 feet deep in red, brown, grey, and greenish sands of the Upper Greensand, capped most irregularly by chert detritus. Irregular broken bands of chert, moreover, appeared at various levels. Here unquestionably the Upper Greensand, which comprises sands with bands of chert of varying thickness, had been disintegrated by the action of the weather, and the mass had been affected by a certain amount of land-slipping. Further on by Hartgrove Farm there was much rough chert detritus resting on the Greensand.

A different deposit was exposed to the south of Hartgrove Farm, being reddish brown loamy clay with angular and unworn flints, 10 or 12 feet thick. This may belong to the beds noted further on by Combe Pyne station. In the intermediate ground, comprising moorland and plantations, the Upper Greensand was exposed in places, but the land was for the most part covered with angular chert detritus, or "run of the hill" from the high ground of Shapwick Hill on the east.

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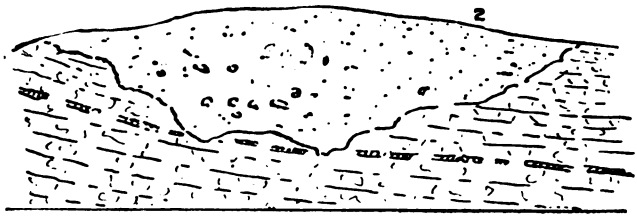
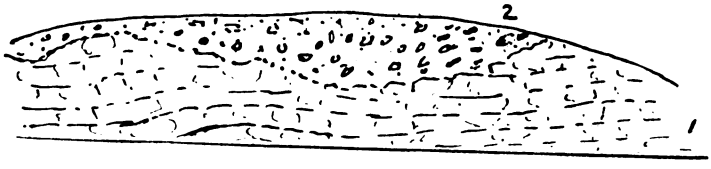
Mr Woodward.

East side.




West side.




Figs. 4 and 5. Sections near South Ground Linhay, south of Axminster.
2. *Débris* of Upper Greensand—sand and chert.
1. Red and variegated Keuper Marl with band of hard pale marl.

Where the railway cuts the northern part of Combe Pyne Hill, a cutting (not completed) showed 3 or 4 feet of loamy flint drift resting on 5 or 6 feet of irregular and disturbed pipe-clay, whitish and pinkish in colour, and with black coatings on the joints, in irregular pockets, and on imbedded stones of flint and quartz. The black coating was determined by Dr. Pollard to be manganese-ore. The stones occurred in a band, the quartz pebbles varying in size from that of a pea to ¾ inch in diameter.

The appearance of these deposits suggested a possible trace of Bagshot Beds. Quartz pebbles had not been noticed in the plateau-deposits previously met with along the railway.

The suggested age of the beds was confirmed in cuttings further south, where unctuous white clay and white sand with flints were exposed. The beds evidently formed part of the series seen on the northern part of Combe Pyne Hill, but they were much concealed beneath a downwash of angular flint and chert detritus.

The clean white sand had every appearance of Bagshot sand, and on submitting a sample to my colleague, Mr. H. H. Thomas, he determined the ingredients as noted in the accompanying statement. The minerals are suggestive of derivation from a granitic area.

*NOTES ON THE BAGSHOT SAND, FROM COMBE PYNE, IN DEVONSHIRE.*
*BY H. H. THOMAS.*

This sand, which is very fine, is of a dirty white to a pale yellow colour, and is gritty between the fingers.

Large grains are rare, and there is a complete absence of calcareous matter in the form of carbonates

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Mr. Thomas.

The following are the chief minerals which constitute the heavy residue—that part of the sand with a specific gravity greater than 2·9 :—

*Rutile.* This mineral, which is perhaps the most prevalent of those in the heavy residue, occurs for the most part in rounded prisms of an amber colour. Polysynthetic twinning is common, the striæ making about 25° with the long axis. Geniculate twins also occur, following the same law of twinning as the above ; the axes of the individuals being inclined to one another at near 65°.

*Zircon.* In rounded prisms and grains with fresh fracture, containing many colourless inclusions arranged parallel to the prism faces and to the pyramid (111).

*Tourmaline.* This mineral occurs in dark brown pleochroic prisms, which in some cases show the outlines of the simple rhombohedra. The grains have not been rounded to any great extent.

*Leucoxene.* In yellow, green, and white, almost opaque grains, all more or less rounded ; in some cases there is evidence of an unaltered dark core, probably *Ilmenite.*

*Micas.* A white mica occurs in minute flakes.

Of the lighter residue, Quartz and Felspar are the main constituents: —

*Quartz.* In small angular grains, full of minute inclusions. Very few grains are rounded, and there is no evidence of secondary growth. As might be expected, this mineral forms the main bulk of the sand.

*Felspar.* The only felspar noticed was orthoclase ; it exists in rectangular cleavage fragments, all more or less decomposed, in some cases so much so as to render them almost opaque.

This mineral, although not so plentiful as the quartz, occurs in fair quantity.

Round dark grains were found to consist of an earthy material, giving the reactions of manganese.

These grains probably consist of carbonaceous matter (? wood), associated with an earthy oxide of manganese.

Mr. Woodward.

Additional evidence in support of the Bagshot age of the beds was obtained in the long cutting east of Combe Pyne Station. This cutting is 35 feet deep in places, and although unfinished it showed a series of white, red and mottled stony clays and grey loam overlaid by rough flint and chert gravel. The clays had a marked inclination towards the east, but the dip was obscured in the upper part of the section, probably owing to the fact that the beds have suffered from prolonged sub-aërial action. The character of the deposits, and the remarkable inclination of the layers reminded me at once of the white and coloured clays and sands and coarse gravels which border the Bovey Basin at Wolborough and other places near Newton Abbot—beds which I had many years ago regarded as equivalent to the plateau drifts of Haldon,* and which have recently been shown by Mr. Reid to be for the most part of Bagshot age.† (Fig. 6.)

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* *Quart. Journ. Geol. Soc.*, vol. xxxii., p. 234.

† *Ann. Rep. Geol. Survey* for 1895 ; and *Quart. Journ. Geol. Soc.*, vol. liv., p. 234.

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Mr. Woodward.

It is noteworthy that in the last *Summary of Progress* (for 1900, p. 122) Mr. Reid remarked that "Though the mapping of the Hampshire Basin has now been completed, it is probable that a chain of outliers of the Bagshot river-gravels will connect the Eocene of Dorset with that of Bovey Tracey in Devon—indeed, several outliers of this gravel have already been mapped."

Thus outliers have been traced as far west as the neighbourhood of Maiden Newton, in Dorsetshire, by Mr. L. W. Hinxman and Mr. E. E. L. Dixon.*

Fig. 6. Section east of Combe Pyne Station.
Bagshot Beds. White and red stony clays and gravels.

The foregoing remarks by Mr. Reid were not present in my mind while examining the cutting at Combe Pyne; it was therefore an additional satisfaction to read them afterwards. During the years 1873 and 1874, Mr. Ussher and myself, and in 1874 Mr. Reid also, were engaged in re-surveying the country round Honiton, Axminster, and Lyme Regis, and we were then perplexed to account for the plateau deposits. Some were evidently local, but in other tracts there were foreign materials, large pebbles of quartz, and quartzite, for which it was difficult to account. I was led to treat as probably Boulder Clay, a mixed deposit found at Yarcombe, between Honiton and Chard.† It seems quite likely now that this deposit, which comprised greenish-yellow clay, reddish-brown and pale-coloured sand, and gravel with quartz and quartzite, as well as flint and chert, may belong to the Bagshot series.

Leaving Combe Pyne Hill, the new railway extends eastwards towards Uplyme, along a scarp of Upper Greensand just below the Chalk. The chert beds of the Greensand here, as elsewhere, were of somewhat irregular occurrence in the sands, and where shattered by frost, they have formed a kind of angular drift on the slopes.

Beyond the viaduct which crosses the deep valley south of Cannington Farm, the Greensand was well exposed with little detritus on top, but further on below the steep scarp of Horseman's Hill, which is formed by the chert beds, the ground was covered with cherty *débris*.

West of the Uplyme road the chert and flint detritus was seen to rest most irregularly on grey and greenish sand of the Upper Greensand, owing chiefly to slips. Here the gravel contained a good deal of very red clay, with irregular brown and blackish

* *Summary of Progress* for 1898, p. 145; for 1900, p. 122.
† *Geol. Mag.*, 1874, p. 335.

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layers, but it was less distinctly stratified than that in the lower part of the Combe Pyne cutting. Mr. Woodward.

Towards Lyme Regis station a somewhat similar section of 9 or 10 feet of gravel was seen above dark green sand belonging to the Upper Greensand.

## FURTHER NOTES ON THE CUTTINGS ALONG THE SOUTH WALES DIRECT RAILWAY.

BY H. B. WOODWARD.

Particulars of the strata exposed along the cuttings of this railway were given in the *Summary of Progress* for 1898, pp. 188-192, from notes furnished by Mr. A. Strahan and myself. During the autumn I re-examined the cuttings from Wootton Bassett to Alderton. In the upper part of the cutting west of Hunt Mill Lane, Wootton Bassett, a band of coarse oolite belonging to the Corallian was exposed below the rubbly coral limestones and clays which form the upper part of that formation. No evidence of Lower Calcareous Grit was discernible, and it is possible that the beds are faulted against the Oxford Clay, but as the cutting had been sloped, precise evidence was not obtained. Onwards to near Hullavington the line has been nearly completed and all the cuttings have been sloped. Scattered flints (some of Eolithic type) are to be found above the Oxford Clay west of Brinkworth, and they are strewn over the ground to the north on Ramps Hill and beyond. These flints are gathered from the fields for road-mending, and they sometimes occur in sufficient mass for the opening of a shallow gravel-pit.

The cutting west of Bradfield Farm, Hullavington, had been considerably deepened since my former visit, and it exhibited an interesting section of Cornbrash resting on inclined layers of Forest Marble as shown in the accompanying diagram. (Fig. 7).

While the Cornbrash oversteps the inclined layers of Forest Marble clay and shale, these beds of Forest Marble themselves rest irregularly on a lower portion of the formation, a sandy division: so that there is evidence of a double (minor) unconformity—due partly to current-bedding and local erosion. At the top of the Forest Marble clay there is a thin oyster-bed made up of variable forms of *Ostrea Sowerbyi*. This is a feature of some interest. Oyster-beds occur here and there throughout the Jurassic system, but this is the most prominent bed that has been noticed in the Forest Marble of the west of England.

During an excursion made in May 1901 by the Geologists' Association,* the cutting was examined, and attention was then drawn by Mr. W. Whitaker to the fact that Cornbrash here lies on different divisions of the Forest Marble.

Sections of equally noteworthy character were observed by myself in cuttings along the Midland and South-western Junction Railway near Cirencester.†

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* *Proc. Geol. Assoc.*, vol. xvii., p. 144.

† *Jurassic Rocks of Britain*, vol. iv., p. 366.

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Mr. Woodward.

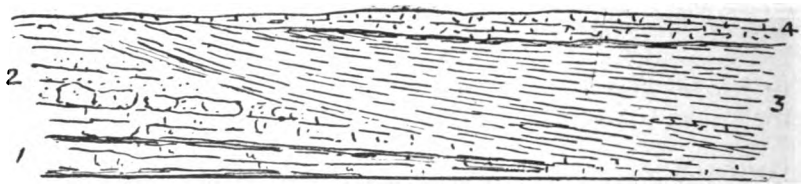


Fig. 7. Cutting west of Bradfield Farm, Hullavington.
4. Cornbrash. 2. Sands, sandstone and shaly beds.
3. Shales with thin calcareous grit. 1. Limestones, shales and clays.

It is not easy to build up the sequence of Forest Marble, and here and there small faults affect the strata and their amount and throw cannot always be definitely ascertained.

The following appears to be the succession between Hullavington and Alderton:—

Cornbrash.

| | | |
|---|---|---|
| Forest Marble. | Oyster Bed with *Ostrea Sowerbyi* : - - - | 8 in. to 10 in. |
| | Clays with thin layers of calcareous grit with track-markings - - - - - - | 20 ft. |
| | Shales and limestones - - - - - - | 5 „ |
| | Sands and hard calcareous sandstones - | 20 „ |
| | Oolitic and shelly and gritty limestones, with lignite and shales—false-bedded—and to some extent replacing one another - - | 35 to 50 „ |
| | Blue clay with occasional bands of limestone | 25 „ |

Great Oolite. Pale oolite. Seen to depth of 18 feet at Alderton.

The sands and sandstones are approximately equivalent to the Hinton Sand and Sandstone of William Smith. They exhibit large doggers with the well-known pot-lid structure. The limestones are manifestly impersistent.

## REPORT ON THE EXAMINATION OF THE SECTIONS AT THE RESERVOIRS AND ALONG THE COURSE OF THE AQUEDUCT OF THE BIRMINGHAM CORPORATION WATERWORKS, RHAYADER TO FRANKLEY, 1901.

BY T. C. CANTRILL.

During the month of August about a fortnight was devoted to examining the sections at the reservoirs west of Rhayader and along the course of the aqueduct thence to Frankley near Birmingham.

The Silurian sequence of Rhayader has been described in great detail by Mr. H. Lapworth.* According to him the reservoirs in the Elan and Claerwen valleys are situated chiefly on the slates which form the Dyffryn Flag subdivision of the Gwastaden Group or Lower Llandovery rocks of the district. There are many natural sections and the works have opened up others.

* *Quart. Journ. Geol. Soc.*, vol. lvi (1900), p. 67.

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Mr. Cantrill.

The dam of the Dolymynach reservoir is being constructed on a grit bed underlying cleaved shales and forming a compressed anticline and syncline trending north-east and south-west, and traversed by two well-marked thrust-planes along which movement has taken place from the north-west. This grit appears to be part of the Cerig Gwynion Grits which immediately underlie the Dyffryn Flags and form the base of the local Lower Llandovery.

The aqueduct leaves the Carreg-ddu reservoir by a tunnel carried through the Dyffryn Flags of Craig-y-Foel, across the well-marked Abernant Fault and into the Caban Group or Upper Llandovery.

East of Elan Village the pipe-track passes into the Rhayader Pale Shales or Tarannon Beds, and continues in this subdivision as far as the western side of the Wye Valley south of Rhayader. It then descends the sequence into the Gwastaden or Lower Llandovery, the Caban Group having apparently been overlapped. The Gwastaden Group consists of various shaly, flaggy, and conglomeratic beds subdivided into several zones characterised by peculiar graptolites. The pipe-track gradually crosses these subdivisions and passes off the lowest at Gaufron, 2 miles east of Rhayader. It then enters the district occupied by the dark shales with grit-bands believed by Mr. Lapworth to be of Bala age. Of this district he remarks* that certain dark seams in the arenaceous rocks yield *Diplograptus foliaceus*, Murch., and other graptolites. Beyond this district of Nantmel we leave the ground examined by Mr. Lapworth.

East of the river Clywedog cleaved brown shales are introduced by a bold feature which crosses the district in such a way as to suggest that it is due to newer beds markedly unconformable to or faulted against the Ordovician, and the aqueduct is carried through this feature by the "Penybont Tunnel" into the Ithon Valley. The tip at the western end of the tunnel in Gwgan Hall Wood is composed of dark flags and shale, with pieces of conglomeratic rock; no fossils were observed, and there was nothing to show the exact source of the *débris*. Probably most if not all of this material came from the Ordovician beds. Surface exposures along the course of the tunnel show that the newer strata dip on the average in an easterly direction. These beds are shown on the Geological Survey map [old series, Sheet 56] as belonging to the Wenlock Series. But the brown and grey shales and sandstones forming the tip (presumably from the eastern part of the tunnel) south of Bryn-hyferth (= Bryn-rhyfedd on the old series map) being full of graptolites, some of these were collected by Prof. Watts and myself, and have been identified by Miss Ethel M. R. Wood, of Birmingham University. She reports as follows:—

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* *Op. cit.*, p. 96

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Mr. Cantrill.

"On tip at Bryn-hyferth Farm [Six inch map, Radnor, 16 S.E.], 1¼ miles north-west of Penybont Village, graptolites occur in great abundance on thin splintery brown shales. I have identified *Monograptus colonus*, Barr., *M. Nilssoni*, Barr., *M. bohemicus*, Barr., *Retiolites spinosus*, Wood. These graptolites are characteristic of the *M. Nilssoni* zone in the L. Ludlow shales, which occurs above the *M. vulgaris* zone and below that of *M. scanicus*. This zone is quite similar, both lithologically and palæontologically, to that in the Builth District, and also agrees closely with the same zone in the Long Mountain.

"In somewhat more flaggy beds at the same locality occur *M. colonus* in abundance, associated with one or two fragments of *M. bohemicus* and *M. Nilssoni*. These belong to the same zone as the above."

It thus appears that the Silurian beds here must be referred to the Lower Ludlow Shales and not to the Wenlock Series.

Roadside exposures at Tre-grugyn, at the supposed junction of the Ludlow and Wenlock north of Llanfihangel Rhyd Ithon yield graptolites, among which Miss Wood has identified *Retiolites spinosus*, and remarks that she has not found this hitherto outside the *M. Nilssoni* zone in the Lower Ludlow. This, together with the evidence of the graptolites from the Penybont Tunnel, makes it doubtful whether there is any foundation for the position of the Lower Ludlow base here.

Numerous exposures of the Ludlow beds occur thence to beyond Knighton. The Old Red Sandstone west of Brampton Bryan where crossed by the pipe-track is overspread with gravel, and the solid rock does not seem to have been exposed. East of Brampton Bryan gravel extends as far as Walford, beyond which the Silurian beds are more of the classical Shropshire type, and contain various bands of limestone. The Aymestry Limestone forms some fine cliffs on the west side of the Teme south of Downton. Some of the beds are full of *Pentamerus Knightii*. Beyond this point the pipe-track closely follows the top of the Aymestry Limestone. The Passage-beds into the Old Red at Ludlow do not seem to have been exposed, and east of the river Teme the pipe-track enters and continues for some distance in the lower beds of the Old Red Sandstone. It crosses the Ludlow series of Caynham Camp and revealed below the Aymestry Limestone some thickness of shales not shown on the map. (Sheet 55.)

The "Studley Tunnel" under the southern promontory of the Titterstone Clee Hill commences north of the village of Hope Baggot, in the Old Red Sandstone. From information supplied by Mr. J. McKie, the engineer in charge, it appears that the beds at first encountered consist of the ordinary red and green marls and soft shaly red sandstone; but at about 1400 feet the heading passed into harder beds of pebbly light-red coarse sandstone, the pebbles being chiefly of vein-quartz. This bed had not been pierced at the time of my visit. There is little doubt that this represents the Upper Old Red Sandstone, or at least the highest Brownstones of other districts, while the marls with cornstones which occupy the lower horizons and extend from Ludlow to the Wyre Forest Coalfield belong to the Lower Old Red. The eastern heading of the Tunnel was at the time of my

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visit about 1100 feet in; it had passed from Old Red through the Carboniferous Limestone into Millstone Grit and possibly Coal Measures—various yellow and grey grit *débris*, together with clods, shales, and fireclays, occurring on the tip. If these latter belong to the Coal Measures, the lines on the map will need some little adjusting, as the Coal Measures are shown as forming only a capping at the top of the hill where crossed by the line of the tunnel. Mr. Cantrill.

Beyond Studley the aqueduct crosses the broad tract of Lower Old Red, extending from Clee Hill to the Wyre Forest. The Coal Measures of this latter coalfield where crossed by the pipe-track —from Malpass Wood to Hawkbatch Farm on the Severn— appear to consist of two groups: a lower, of variegated marls with yellow and green sandstone, in which the crop of a coal has since been cut through at Silligrove; and a higher group of grey and yellow sandstones with thin pyritous coals and one or more bands of *Spirorbis* limestone. The lower group has some likeness to the Old Hill Marls of South Staffordshire and the Etruria Marls of North Staffordshire; while the higher, as seen at Winwoods and Kingswood, and again at Woodhouse Farm near Button Oak, may represent the Halesowen Sandstones of the former district and the Newcastle-under-Lyme beds of the latter.

The junction of these Coal Measures with the Lower Old Red of Trimpley appears to be either a very sharp overfold or more probably a fault, the Old Red being thrust from the east over the Coal Measures. The lowest beds of the Trimpley anticline appear to be certain flaggy greyish-red beds and yellowish-grey tilestones which crop out at Trimpley Church and Littlegains. From these beds numerous fish-remains were obtained by G. E. Roberts,* who considered them to represent the uppermost Silurian or Passage-beds of other districts.

Beyond the Old Red Sandstone of Trimpley the Trias is entered and extends as far as Hagley, near Stourbridge. The sections call for no particular note. The so-called Lower Permian beds of the South Staffordshire Coalfield were then entered. The rocks consist of red and crimson marls, mottled blue, with some pale-red sandstone and occasional bands of conglomeratic cornstone. The presence of bands of *Spirorbis* limestone in similar beds at Sandwell and Hamstead Colleries on the east side of the coalfield had long been known, but no outcrops in the "Permian" ground to the south had previously been observed. The excavations for the pipe-trench have now exposed outcrops of such limestones at three different points between Hagley and Frankley. The first locality lies 100 yards west of Wassel Grove Lane at Hagley; the second is on the edge of Offmoor Wood, north-north-east of the Fox Inn at Romsley. The third is at the terminal reservoir at Frankley, where the limestone contains the characteristic fossil. From information supplied by Mr. Fred. W. Macaulay,

* *Rocks of Worcestershire*, 1860, Chap. vii.

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Mr. Cantrill. the engineer in charge, it appears that the limestone outcrop was met with in some excavations for the filter-beds at about 250 yards N. 20° W. from Frankleylodge Farm. The bed was about 1 foot or 1 foot 6 inches thick, the stone being rather rotten and much broken up. The position of this band is not far below the bottom of the "Permian" breccia as drawn on the map (Sheet 54 N.W.); and whether this latter is conformable or not to the red marls and sandstones, there is little doubt that the limestone here is higher than the other two bands, and that there are three distinct bands of *Spirorbis* limestone in these red rocks.

## NOTES ON THE GOOLE AND MARSHLAND LIGHT RAILWAY.

BY W. GIBSON.

The Goole and Marshland Light Railway, now under construction, passes over the more elevated portions of the Isle of Axholme, and exposes some good sections of the solid rocks which are rarely to be seen in this part of Lincolnshire.

To the north of Haxey Village a cutting, one mile long and 30 to 40 feet deep, is being excavated in Keuper marls. These consist of red and green sandy marls, containing "skerries" and bands of red sandstone a few inches thick. Fibrous gypsum, in the form of isolated plates or in irregular bands from two inches to four inches thick, is developed throughout. The stratification is irregular, a feature common to the gypsiferous portions of the Keuper marls elsewhere.

The marls are overlain by a warpy silt 3 to 4 feet thick; the junction with the marls is sharp and even, and forms a line of demarcation for nearly the entire length of the section to near Haxey Village, where blown sand forms the surface-deposit. The warpy silt lies close to the 100 feet contour, and has the appearance of being of aqueous and not of æolian origin. If this is correct it implies a certain amount of elevation; but the relation of the warpy silt to the other superficial deposits of the district is not clear.

In making the foundations near the drain north of Haxey Station Mr. M. F. Glover, the engineer in charge of this section, proved sand for over 26 feet. A ferruginous band was passed through six feet below the surface.

Blown sand appears to occupy much of the surface passed over by the line from the north end of the cutting at Haxey to Epworth.

A cutting has just been commenced one half of a mile north-west of Epworth Church. The section exhibits Keuper marls of a very similar type to those of the Haxey cutting, but the bands of gypsum are slightly thicker.

Between Epworth and Crowle Town the line has not been laid out.

Crowle Hill, near Crowle Town, has been partly cut through from the north. Warpy sand 3 to 4 feet thick forms the surface of the section. This rests on Keuper marls containing thin

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bands of gypsum, like those in the Haxey and Epworth cuttings. The stratification is more evident, and a dip of 15 degrees east can be clearly made out. The north end of the section shows blown sand overlain by the talus from an old quarry through which the line passes. Mr. Gibson.

No sandstones have been met with in any of the sections of sufficient hardness or thickness to form building stones. These evidently occur lower down in the sequence, for in the Reedness boring, which is on the line of strike of Crowle Hill, the sandy marls were 272 feet thick, after which sandstones were met with.*

North of Crowle Hill the line passes over warped land. As shown in the excavations for the telegraph posts the warp lies on peat and is nearly all of artificial origin.

Peat is being extensively dug for litter south of Reedness station. At this spot numerous stumps of trees, several standing erect, are exposed in the excavations for the line and station buildings. They are overlain by a thin layer of warp.

## II. PETROGRAPHICAL WORK.

The material forwarded to the Petrographical department in London for examination and report during the year 1901, has to a very large extent been furnished by those areas of the Scottish Highlands which lie to the east and south of the Great Glen, and has consisted, as in former years, principally of metamorphic and intrusive rocks. The approaching publication of several sheets and descriptive memoirs from this region has rendered necessary the revision of the petrographical collections which have been made during the progress of the field work, and has suggested problems for special investigation. This seems, in consequence, to be a favourable opportunity to discuss some of the outstanding results of the study of the rocks of the Southern Highlands of Scotland. Dr. J. S. Flett.

The groundwork of this area is formed of masses of sedimentary rock, the age of which is at present uncertain, and these differ to an extraordinary degree in their state of metamorphism in the various sub-districts included in this extensive country. Omitting for the present all consideration of the rocks which form the narrow strip which is supposed to be of Arenig age, and which lies on the southern margin of the Highlands, and is apparently bounded by faults on both sides along most of its extent, we find among the Highland rocks some in which the metamorphism is no more advanced than in the greywackes or shales of the Southern Uplands. So little have they been affected by the earth movements and other agencies which induce metamorphism that they can hardly be distinguished from the Arenig (?) rocks of adjacent areas. In the finer shales the original bedding is so little obscured in some cases by the development of slaty cleavage that the geologist is at once impressed by the possibility that a

* "The Geology of parts of North Lincolnshire and South Yorkshire." *Mem. Geol. Survey* (1890), p. 7.



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Dr. J. S. Flett. careful search might reveal the presence of fossils. The grits are quite as little modified; the original clastic structures are perfect; the original clastic micas are visible in abundance; while cataclastic structures and new micas are surprisingly little in evidence. A re-examination of the Highland series in the vicinity of Aberfoyle has confirmed the opinion already formed by the field officers that the metamorphism in that quarter is of the most rudimentary kind.

Mr. J. B. Hill in his paper on the progressive metamorphism in the neighbourhood of Loch Awe* has described very similar rocks from that region, and in Banffshire, many miles to the north-east of this, Mr. Hinxman has observed on the headwaters of the Deveron (Sheet 85) grits and shales, which, though often indurated by the contact action of adjacent intrusive masses, have still their clastic characters very perfectly preserved.

Such areas of low metamorphism, however, are not usually extensive, the largest being probably that which stretches along the southern border of the Highlands from Cowal through Aberfoyle and Callander into Perthshire, where the rocks gradually assume that highly crystalline character which Mr. Barrow has described† in the regions drained by the rivers North Esk and South Esk, in Forfarshire. Throughout this tract the degree of metamorphism is low as a rule, though not everywhere the same. But as we pass northwards the metamorphism increases with great rapidity. There are cases in which, in little less than a mile as measured across the strike, coarse felspathic grits can be seen to pass through various intermediate conditions into granulitic quartzose gneisses in which clastic structures have been entirely obliterated. Most interesting to the student of metamorphism are sections such as may be observed near the Trossachs Pier on Loch Katrine, or on the west shore of Loch Lomond, near Inverbeg, where, in a single exposure, all stages in the passage of a grit into a foliated gneissose rock can be exemplified. In the forthcoming explanations of Sheets 38 and 55 the materials obtained from a study of such sections, and the conclusions they lead to, will be discussed in reference to the geology and structure of the districts in which they occur.

The great sedimentary series of the Southern Highlands—conglomerates, grits, greywackes, shales, limestones, and the problemetical "Green Beds,"—is penetrated by igneous intrusions, which, as regards their age and geological relations, fall naturally into two subdivisions. Of these one is the older and has preceded part, at least, of the movements to which the area has been subjected. They are, in consequence, foliated, though it is

* J. B. Hill. "On the Progressive Metamorphism of some Dalradian Sediments in the Region of Loch Awe," *Quart. Journ. Geol. Soc.*, vol. lv., p. 470, 1899.

† George Barrow. "On Silurian (?) Rocks in Forfarshire and Kincardineshire along the Highland Border," *Quart. Journ. Geol. Soc.*, vol. lvii., p. 328, 1901. "On an Intrusion of Muscovite-biotite Gneiss in the S.E. Highlands of Scotland, and its Accompanying Metamorphism," *Quart. Journ. Geol. Soc.*, vol. xlix., p. 330.

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important to remember that, like the sediments they pierce, they vary much in degree of their metamorphism. Some are, in fact, gabbros, norites, peridotites, or granites, with their original minerals well preserved, and exhibit the characteristic structures of plutonic igneous masses. On the Deveron, in Banffshire, in the district already mentioned, where the sediments show so little alteration (Sheet 85), there are gabbros and serpentines which are indeed affected by the earth movements which resulted in the foliation of the area, but are still so little modified that their igneous structures are very well seen. As metamorphism advances they pass through flaser gabbros into epidiorites and hornblende-schists, and this last is the prevalent type of basic intrusive rock throughout the Southern Highlands. Dr. J. S. Flett.

The porphyritic andesitic basalts of the Loch Awe series as described by Mr. J. B. Hill are further examples of the perfect preservation of igneous structures in the rocks of this group.

It is not only in the degree of their metamorphism that great variations can be traced. In chemical composition they exhibit differences which are quite as great. As already stated, they are mostly rocks of basic affinities, epidiorites and hornblende-schists. With these occur peridotites and serpentines, with various kinds of talcose, actinolite-schists, which have developed from the shearing of ultra-basic masses. But acid gneisses, which correspond to biotite- and biotite-hornblende-granites are also known, as has been shown by Mr. Kynaston in the district around Dalmally, Argyllshire, and the passage from the hornblende-schists to the older granites and gneisses can now be bridged over almost completely.

Another feature worthy of mention is the presence of fine-grained and vesicular igneous rocks in association with others of the coarse-grained type which predominates.* In Sheet 85, on the Deveron, in Banffshire, Mr. Hinxman has mapped fine-grained vesicular hornblende-schists, the vesicles being filled with calcite. When the rock weathers it has quite a pumiceous aspect. It seems quite possible that these may be contemporaneous lava flows, but the very similar rocks from Loch Awe, Mr. J. B. Hill regards as intrusive. There can be no question that, as a whole, the hornblende-schists are intrusive sheets. This can often be proved by their transgressive junctions and their fine-grained chilled edges. Where the original structures can be traced they are those of slowly cooled masses. Occasionally they induce contact alteration in the sediments they break through. This, in most cases, amounts only to a slight induration, but on the Blackwater, in Sheet 85, a slate can be shown to pass at its contact with an intrusive mass of gabbro, epidiorite and serpentine, into a silvery mica-schist with large crystals of staurolite and andalusite. Such evidence of thermal alteration, however, is exceptional.

The rocks which are being mapped by the Geological Survey as "Green Beds" include a very great variety of petrographical

* *See* Mr. Kynaston's remarks, *Summary of Progress of the Geological Survey of the United Kingdom* for 1890, p. 33.



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Dr. J. S. Flett. types. They are a group of sedimentary rocks characterised by the abundance of chlorite, epidote, or hornblende, and this gives them a green colour and a peculiar method of weathering. In the south-western part of the Southern Highlands, in Cowal, and on Loch Lomond, they are mostly chloritic and epidotic grits, and rarely contain hornblende. But the "Green Beds" of Central Perthshire, and of Forfarshire, are rich in hornblende and constitute a remarkable series of hornblende-schists of sedimentary origin. Mr. Cunningham Craig has paid special attention to the "Green Beds,"* and in the valley of the Tay, near Aberfeldy (Sheet 55), he has found that it is often a matter of some difficulty to distinguish between the intrusive hornblende-schists and those belonging to the "Green Bed" series. As a rule indications are not wanting which enable the field-geologist to discriminate between them. The "Green Beds" may be seen to pass gradually into sheared grits by increase in the proportion of quartzose detritus; the intrusive hornblende-schists show fine-grained chilled edges and the coarser central parts of the sheets have a quite distinctive appearance. But it is astonishing how closely the rocks of one group may resemble those of the other. Some "Green Beds" are fine-grained, well foliated hornblende-schists, with a little quartz and felspar, and not uncommonly biotite and garnet. There is very little to distinguish them from the finer epidiorites, but a careful search of the outcrops will usually show the presence of pebbly bands containing large, well-rounded grains of quartz, obviously clastic in origin. Where the metamorphism is greater the pebbles are drawn out into granulitic quartzose augen, and appear gradually to blend with the schist and become lost in the foliated matrix of the rock.

Of the older granites little that is new has this year been ascertained. They are well known to include types ranging from extremely acid muscovite-gneisses and pegmatites to biotite-gneisses such as that of Ben Vuroch, and are believed to have effected great contact metamorphism in certain districts.

During the year 1901 the principal area of the newer granites in Scotland to be submitted to microscopic examination was that of Ben Rinnes, in Elginshire, which proved to contain the usual association of biotite-granite, diorite and augite-diorite, with subsidiary masses and veins of muscovite-granite, aplite and muscovite-pegmatite. On the east side of Loch Lomond a mass of hypersthene-diorite, or hyperite, already known, has been further examined, and shows some interesting contact phenomena. At Netherly, near Rothes, Elginshire, a mass of diorite, one of the facies of the newer granite of Ben Rinnes, has converted the micaceous schists of the Moine series into cordierite-hornfelses, with andalusite, sillimanite, and garnet.

The dyke rocks of the Southern Highlands, associated with the newer granites, have received much attention and study, both in the field and with the microscope. Their great abun-

*Summary of Progress of the Geological Survey of the United Kingdom for 1900, p. 25.

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dance and diversity makes them a peculiarly fascinating subject. Dr. J. S. Flett.
Their relations to the newer granites are always sufficiently close to establish a community of origin, though there are cases in which they cut the granites, and others in which they are altered and hornfelsed by adjacent granitic intrusions. Two distinct series of dykes can be established—the porphyries (and porphyrites) and the lamprophyres. Space will not permit of a discussion of the classification of the dyke rocks as a whole, but a few remarks may be made on the most difficult group, the lamprophyres.

Owing partly to their inherent variety, partly to the great readiness with which they decompose, and partly to their propensity to develop distinct facies in different parts of their course, it is no easy matter to say exactly to what subdivision of the group any particular example is to be assigned. Their essential minerals, biotite, brown hornblende, orthoclase, and plagioclase are often all present in the same specimen, and may occur in any relative proportion. The classification at present in use is simple, and appears to be the most satisfactory that can be proposed, though admittedly there are individual occurrences which lie on the border line between the various groups. The dykes consisting principally of biotite and orthoclase are minettes; of biotite and plagioclase, kersantites; while those in which hornblende preponderates fall into the vogesites (orthoclase and hornblende), and the spessartites (plagioclase and hornblende). For rocks containing both biotite and hornblende there is a choice of terms: mica-vogesite or hornblende-minette, and mica-spessartite or hornblende-kersantite, the use of which will depend on whether hornblende or biotite is the dominant ferro-magnesian mineral. Thus, if the section contains orthoclase with hornblende and a subordinate amount of biotite, the last named may be regarded as an accessory mineral, and the designation employed would be mica-vogesite or mica-bearing vogesite.

The grouping adopted is, however, entirely artificial, and it should not be forgotten that a vogesite dyke may pass into minette or spessartite as it is traced along its course. A further difficulty arises from the rapid decomposition which characterises the lamprophyre group. They are often so charged with secondary carbonates that the determination of their felspar is impossible. For these and other reasons it is advisable to retain the generic designation "lamprophyre" to mark the outcrops as shown on the maps.

A word may be added regarding the term spessartite and the relations of the spessartites to the camptonites. As Rosenbusch has pointed out there are two series of lamprophyres, consisting essentially of plagioclase felspar and hornblende, which differ so greatly from one another in physical characters, chemical composition and geological affinities, that they cannot be united. The spessartites belong to the granitic-dioritic magmas, and are associated with vogesites, minettes, and kersantites. The camptonites are associated with alnöites, monchiquites, and

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Dr. J. S. Flett. fourchites, and seem to have been mostly emitted from foyaite, essexite, and theralite magmas. The spessartites are rather of intermediate, the camptonites of highly basic character. The deep red-brown hornblende of the camptonites differs considerably from the paler, often greenish-brown hornblende of the spessartites, and while quartz is frequent in the latter, it is absent from the former. The augite of the camptonites is dark purplish-brown, of the spessartites mostly pale clear green. At present it cannot be said with certainty that typical camptonites do not occur in the Southern Highlands, as certainly some very basic hornblende bearing lamprophyres are known there, but if they do occur they are rare.

It will be noticed that according to the nomenclature here adopted the "camptonites" will be subdivided into the spessartites and camptonites, and the former are far the most common throughout Scotland.

In the report of this department for the year 1900, Mr. Teall has recorded the very important observation that in Assynt (Sutherlandshire), the dark coloured hornblendic lamprophyres are accompanied by a light coloured felspathic series which he calls "felsites." We have in fact a development of complementary rock suites, a melanocratic and a leucocratic group forming a diaschist-complex as defined by Brögger. It has long been known that in the Southern Highlands there are pale felspathic dykes which have been variously named felsites, orthofelsites, trachytes, etc. Their close relation to the lamprophyres has been noted by more than one of the field officers. They consist almost entirely of orthoclase, are often fine grained and frequently porphyritic. One point is of some importance as regards their origin, and that is that they often show the large corroded xenocrysts of quartz so common in lamprophyric rocks, while quartz is usually absent from the groundmass. It is in every way probable that we have here a leucocratic complementary series to the melanocratic lamprophyres, such as has already been shown to exist in Sutherlandshire.

A further interest has been lent to the study of the dyke rocks of the Scottish Highlands, during the past year, by Mr. Grant Wilson's discovery in Glen Finnan, Inverness-shire, of an occurrence of typical malchites (Rosenbusch). Though they lie outside the area with which we have been dealing in this Report, they are of sufficient interest to merit a brief description.

The malchite dyke rocks from Glen Finnan are grey and fine-grained, consisting of hornblende and plagioclase, never conspicuously porphyritic in the hand specimen, and bear a general resemblance to fine-grained diorites, though on the whole paler in colour than the majority of dioritic rocks. Many of them exhibit a parallel structure which in most cases is the result of fluxion; others are entirely massive.

Although consisting essentially of hornblende and plagioclase they contain as a rule more or less biotite, and this may so increase in quantity as to almost entirely replace the hornblende. A certain amount of orthoclase may be present, and

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occasionally a very little quartz. The accessory minerals include sphene, apatite, magnetite and zircon, while epidote, chlorite, rutile, calcite and muscovite are secondary. One specimen contains orthite. Dr. J. S. Flett.

The hornblende is in small prisms often perfectly idiomorphic in transverse section, but usually elongated and irregularly terminated. Its colour is pale green to dark green, or dark bluish-green, and a very characteristic feature is the presence of minute dark enclosures, which have a regular orientation within the crystal. Often the crystals have a clear centre surrounded by one or two zones dark and turbid with these enclosures, while the external margins may be transparent and free from them.

The biotite is sometimes fox-brown, at other times greenish. It forms small irregular scales devoid of crystalline form. Biotite and hornblende are often aggregated together to form elongated clusters which may be conspicuous in the hand specimen, giving it a streaky appearance, suggesting foliation.

The felspar is mostly plagioclase, but in some of the slides there seems to be a certain amount of orthoclase. The prevailing felspar is perhaps andesine. Quartz in most cases is practically absent.

The structure is commonly panidiomorphic, all the minerals showing some idiomorphism, and this is especially true of the hornblende and the felspar. Some of the slides are really porphyritic, hornblende and plagioclase appearing in small idiomorphic phenocrysts in a groundmass of irregular smaller felspars. The phenocrysts are never large, and the porphyritic character is not obvious in the hand specimens.

Several of these dykes correspond exactly with certain types of malchite as described by Osann,* Chelius,† and Rosenbusch.‡ Others show not unimportant divergence from the original types. A description of these may be conveniently reserved till the mapping of their area of distribution is more advanced, and more is known about their varieties and mode of occurrence.

## III. CHEMICAL WORK.

During the first half-year analyses of rocks and minerals for officers in the field and for the Petrographical Department were made. In June Mr. E. G. Radley was appointed as general assistant in the laboratory. During July and August various analyses were made amongst which might be mentioned a rottenstone and the unaltered limestone from which it is derived, for Mr. Cantrill; a coal from the Colonial Office, and a coal seam which passes laterally into dolomite, for Dr. W. Pollard.

* Osann, A. *Ueber dioritische Ganggesteine im Odenwald.* Mitth. d. Grossh. Bad. Geol. Landesanst, 1892. II. p. 380.

† Chelius, C. "Das Granitmassiv des Melibocus und seine Ganggesteine." *Notizbl. Ver. f. Erkunde*, Darmstadt. 1892.

‡ Rosenbusch, H. *Mikroskopische Physiographie*, B. II., p. 448. 1896

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Mr. Strahan. In August, at Mr. Strahan's request, the chemist was sent to Swansea to confer with and receive instruction from Mr. C. A. Seyler, B.Sc., F.I.C., etc. (Public Analyst for the counties of Carmarthen, Glamorgan, Pembroke, and the Borough of Swansea, and District Agricultural Analyst for the county of Glamorgan), in connection with the analyses of coals from the South Wales Coalfield.

In October the analyses of these coals was commenced, and the first ten samples completed by the end of the year.

Owing to the increased demand on the part of the officers in the field and the Petrographical Department for chemical investigation, it has been found necessary to provide for a second time temporary accommodation sufficient for another worker. For this purpose the gallery leading to the chemical laboratory is to be fitted with a working bench, etc., where Dr. Flett hopes to be able to perform certain investigations in connection with petrological work, as the chemist and assistant are fully employed on problems envolved by the mapping of the South Wales Coalfield.

In the following report the most interesting portions of the year's work in the laboratory will be found, together with a short account of the methods of analysis in use in connection with the coal investigation.

The sincere thanks of the Geological Survey are due to Mr. Seyler, for his kindness in assisting and advising on this investigation.

## ANALYTICAL METHODS IN USE IN CONNECTION WITH THE EXAMINATION OF SOUTH WALES COALS.

The methods in use in connection with this investigation are given rather fully, as it is well known in coal analysis that slight variations in methods (especially in the determination of volatile matter) may produce considerable variations.

Most of these methods are practically the same as those recommended by the Commission on Coal Analysis of the American Chemical Society (*Journ. Am. Chem. Soc.*, 1899, vol. xxi., p. 1116).

*Sampling.*—The samples as received at the laboratory are packed in large biscuit tins which are enclosed in wooden boxes. The weight of the sample is about 20 to 30 lbs. and usually contains no pieces larger than a small orange. All pieces larger than a walnut are crushed in a small Marsden-Blake crusher. The sample is then thoroughly united and quartered in the usual way to about 5 to 10 lbs. This portion is again passed through the crusher, united and quartered to about ¼lb. This is at once transferred to a stoppered bottle and subsequently ground in a coffee mill set fine. The powder is at once transferred to two stoppered bottles, one for analysis, the other being at once tied down and sealed in case it should be required for future reference. The rest of the coal is at once replaced in its tin and also tied down and sealed.

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It should be mentioned that a small quantity (about 150 grammes) of the last quarterings not required for sample are passed through the mill immediately before the sample for analysis is ground, to remove any dust or remains of a former coal left in the mill. The amount of coal left in the mill which might be thought to influence the next sample ground is so small as to render it unnecessary to take the mill to pieces after each time of using. The mill has been taken to pieces several times and on no occasion has more than a gramme of coal been found in it. As at least 300 grammes of each sample go through the mill (not to mention the first 150 grammes alluded to above for cleaning purposes), it will be seen that no appreciable error could arise on this account.

The sample in the condition in which it comes from the mill is used for moisture and volatile matter determinations. This will be alluded to as "coarse moist" coal. For other determinations some of this is ground in a mortar to pass the 50-hole sieve. Moisture is determined on this sample also, so that all results can be calculated to the "coarse moist coal."

Volatile matter is determined on the fine as well as the coarse. In most cases the same value is obtained. Should any appreciable difference be found, both are given.

It is a well-known fact that coal loses moisture when ground fine in a mortar. Many samples of this are given by the Commission on Coal Analysis of the American Chemical Society (*loc. cit.*). Some data obtained in this laboratory in connection with this are given under "Moisture" p. 74.

The sample for specific gravity determination is taken from the last quarterings not required for the analysis sample, and that portion only is used which passes the 8-hole and is retained on the 16-hole sieve. In some cases this sample contains considerably more moisture than the others, partly due no doubt to its not being so long exposed to the air before being bottled.

*Moisture.*—(Determined both on coarse, fine and specific gravity samples.)

One gramme of coal is heated in a Victor Myer bath (toluene being used) for one hour exactly. The temperature obtained is about 105°.

The coal is weighed off between clipped watch glasses, heated uncovered, covered immediately on removal from the bath and allowed to cool in a desiccator.* It is weighed about half-an-hour after its removal from the bath.

The coarse moist sample is also dried in vacuo with sulphuric acid pumice in a Hempel desiccator for twenty-four hours. More moisture is often obtained by this method. (Cf. *Journ. Am. Chem. Soc., loc. cit.*)

The data obtained by drying at 105°. for one hour are, however, always used in calculating the analyses, as this is believed to be the method of determination most frequently employed.

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* Sulphuric acid pumice is used in all desiccators in this investigation.

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Duplicates (by the same method) should agree within ·1 per cent.

The following table gives moistures determined on different samples at 105°, and on the "coarse moist" coal in vacuo with sulphuric acid:—

| One Hour at 105°. | | | | 24 Hours Vacuo with Sulphuric Acid in Hempel Desiccator. |
|---|---|---|---|---|
| Sample No. | Sp. Gr. Sample. | Coarse Moist. | Fine 50 Hole. | Coarse Moist. |
| 1 | 1·41 | 1·50 | 1·22 | 1·59 |
| 2 | 2·47 | 1·97 | 1·90 | 2·22 |
| 3 | 2·04 | 1·93 | 1·66 | 2·00 |
| 4 | 2·72 | 2·17 | 1·97 | 2·47 |
| 5 | 2·70 | 2·76 | 2·39 | 2·82 |
| 6 | ·80 | ·87 | ·86 | ·82 |
| 7 | 1·55 | 1·58 | 1·10 | 1·61 |
| 8 | 1·10 | 1·12 | 1·14 | 1·10 |
| 9 | 2·48 | 2·12 | 1·73 | 2·16 |
| 10 | 1·79 | 2·13 | 1·79 | 2·08 |

The above figures represent the mean of two or more determinations.

*Volatile Matter.*—One gramme of coal is heated in a platinum crucible with well fitting cover, supported on a platinum triangle over a bunsen giving a flame of 20cm. high for seven minutes exactly.

Bottom of crucible 8cm. above mouth of burner. Gas pressure 50mm. of water.

The dimensions of the crucible employed are—Height, 40mm.; diameter at base, 24mm.; at top, 34mm., capsule cover.

A cylinder of clay or asbestos board of about 12cm. diameter should be used to prevent draughts from influencing the flame.

Loss of weight—Moisture = volatile matter.

Duplicates should agree within

·15% on coals containing up to 15% of volatile matter.
·30% „ „ „ over 15% „ „ „

It should be borne in mind that to some extent at least the value found for volatile matter depends on the size of crucible, tightness of cover, strength of flame, etc. It is therefore important in making this determination to keep as closely as possible to definite conditions in order that the figures found for various coals should be comparable.

The method of Meade and Attix (*Journ. Am. Chem. Soc.*, 1899, vol. xxi., p. 1137) of heating a second time under identical conditions, and subtracting the second loss from the first is being tried, but as yet sufficient data are not available for comment.

*Ash.*—As the main importance of knowing the exact amount of ash in a coal is to get the amount of oxygen as near as possible, it has been considered best to estimate the ash left in the platinum boat from the carbon and hydrogen determination.

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In some cases this agrees perfectly with the value obtained by ashing in a muffle, whilst in others the results vary considerably. Dr. W. Pollard.

This appears to be due to the fact that in the muffle there is less oxidation than in the combustion tube, as might be expected. This seems to be borne out by the fact that the "sulphur in ash" obtained from ash from muffle has (in every case where estimated) been found appreciably lower than the "sulphur in ash" from the boat.

It may also possibly be due to a slight extent to alkalis being partly driven off in the muffle, where the temperature is probably higher than in the boat.* This has, however, not as yet been investigated, but should opportunity subsequently occur, it will be looked into. This variation of ash obtained in the muffle and in the boat has frequently been observed and mentioned by chemists.

Duplicates (by the same method) should agree to within ·1% up to about 4% of ash, and to within ·2% above 4% of ash.

*Fixed Carbonaceous Residue.*—Obtained by subtracting ash, olatile matter and moisture from 100.

*Total Sulphur.*—The method of M.W. and J. Atkinson has been adopted with very slight alteration.

The following description of the method is taken from the report of the Commission on Coal Analysis of the American Chemical Society, 1899, vol. xxi., p. 1116. [See also *Journ. Soc. Chem. Ind.*, Mch. 29, 1886. *Journ. Iron and Steel Inst.*, No. 2, 1896.]

"One gramme of finely ground coke or coal is mixed thoroughly "with five grammes of dry sodium carbonate spread evenly over the "bottom of a flat or shallow platinum dish, and the latter placed "on a rectangular rest made of clay pipe stems inside a muffle, "which though hot is still black. The temperature of the muffle "should be raised gradually during half an hour to clear cherry "redness, and then kept at the latter temperature for 10 or 15 "minutes. The sodium carbonate should not sinter or fuse. The "mass should not be stirred. When the carbon is burned, "usually in about 45 minutes in all, cool, digest with 100 to 200cc. "of warm water, allow to settle, decant through a filter, and wash "twice by decantation, and then on the filter adding a few drops "of a solution of sodium chloride if the residue tends to pass "through the filter. The filtrate is acidified with 12cc. concentrated "hydrochloric acid, and precipitated with barium chloride."

To avoid any possibility of all the sulphur not being oxidised to sulphate before acidifying, it has been thought advisable to add a little bromine water (about 15cc.) before the addition of the hydrochloric acid. It has also been found necessary to heat in the muffle longer than 45 minutes to burn off all the carbon.

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* It is well known that in the determination of ash in plants, potash is not infrequently lost by volatilisation, unless great care is used in the ashing and the temperature kept sufficiently low.

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With these slight deviations the method has been strictly adhered to with most satisfactory results.

The muffle used is a Fletcher, No. 461 (heated by gas). Blind experiments with sodium carbonate have frequently been made, both simultaneously with and separately from sulphur determinations, and in no case has sulphur been found to be absorbed from the gas. It is always necessary to test the reagents used for sulphur, and if found, to apply the correction, as it frequently happens that small quantities of sulphur (which in some cases might be sufficient to give ·1% in the coal) are to be found even in sodium carbonate "Puriss."

Duplicates should agree within ·1%.

*Sulphur in ash.*—This is obtained from the ash from the platinum boat after combustion. The ash is evaporated with hydrochloric acid to dryness, taken up with hydrochloric acid and hot water, solution filtered, and the sulphate precipitated with barium chloride in the usual way. The amount of sulphur obtained here substracted from the "total sulphur," gives "combustible sulphur."

*Nitrogen.*—Kjeldahl's method has so far been exclusively used, although it is proposed to do a certain number by combustion with soda lime for the sake of comparison. 1 gramme of coal is heated with 20cc. concentrated sulphuric acid, 8 grammes dry potassium sulphate, and a bead of mercury till colourless. Allow to cool, and pour into a flask of about 1000cc. capacity, containing about 200cc. water, rinse out, etc., and when cold add 80cc. of a 50% solution of sodium hydrate, and 20cc. of a 4% solution of potassium sulphide. Distil (using a good splash head) collecting distillate in 20cc. $\frac{n}{10}$ acid. Titrate back $\frac{n}{10}$ or $\frac{n}{20}$ alkali. Indicator Methyl orange.

The mercury (and hence potassium sulphide) may be omitted [Lunge, *Chem. Techn. Untersuchungsmethoden*, 4th edn., Vol. I., p. 228]; in fact, in the determinations made so far one nitrogen estimation has been made with, and one without, the mercury, the only difference observed being that the one with the mercury becomes colourless sooner than that with potassium sulphate only.

Blind experiments should be made, and if necessary a correction applied.

Duplicates to agree to within ·1%.

*Carbon and Hydrogen, Ash.*—Jena glass combustion tubes about 110cm. long and 12 to 15mm. internal diameter are used.

They are filled as follows:—

Copper oxide roll 6 to 8cm.
Space for boat 16 to 20cm.
Copper oxide from wire, not too coarse, about 50cm.
Lead chromate pumice 8cm.
Silver spiral 7cm.

The furnace used is a Fletcher combustion furnace, No. 2 pattern, 36 inches long. The boat is of platinum, 10cm. long. The purifying train (one for air and one for oxygen, with a three-

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way tap, so that the gas can be changed at once) consists of an Emmerling's absorption tube, filled with pumice about the size of peas, which is freshly drenched with 1 in 2 potash before each combustion 35 to 40cm. long, 20mm. internal diameter. Two wash-bottles, the first with potash the second sulphuric acid, followed by two large U-tubes with pumice saturated with concentrated sulphuric acid. (The pumice should be drenched with sulphuric and ignited in a muffle to expel chlorides, etc.) Between the three-way tap and the combustion tube a small sulphuric acid wash-bottle is placed (so that the rapidity of the gas current can be easily watched), followed by a small mercury trap. Dr. W. Pollard.

For the collection of water a U-tube, filled with sulphuric acid pumice, is used. Before each combustion this tube is filled with concentrated sulphuric overnight, and the acid drained off immediately before weighing.

Geissler bulbs are used for absorbing the $CO_2$ with a drying tube 8cm. long, filled with freshly-crushed potash. A small U-tube, with sulphuric acid pumice, is used after the bulbs, to absorb any moisture that might be carried over. This tube, however, seldom gains more than a milligramme. Finally a protecting tube of sulphuric acid pumice. It is scarcely necessary to say that the bulbs and solid potash tube are refilled before each combustion.

Although it is unnecessary to go into details about the combustion, the following points may be worth mentioning.

The boat should contain as nearly as possible ·5 gramme of coal (when dried). This has been found the most convenient amount to work with for accuracy. The fine-powdered coal (50-hole sample) should be used. The boat and coal should be dried at 105° for one hour exactly, cooled, and weighed in a stoppered tube immediately before required.

When the boat is placed in the combustion tube, it is best to rest it on a strip of platinum foil, to prevent it from adhering to the tube or from picking up any fragments of copper oxide.

Before commencing to heat the boat, the copper oxide must be at a bright red heat, the silver spiral and copper roll at a fair red heat, the lead chromate at a dull red heat. When these have been got to the required temperature, the boat is gradually heated (commencing at the copper roll end) in a gentle air current, until the volatile matter is practically all off; the oxygen is then turned on, and the combustion completed in the usual manner.

Duplicates should agree within

Hydrogen ·1%.
Carbon ·2%.

It is of the greatest importance that the copper oxide be hot enough before the boat is heated at all, as presumably methane would be amongst the first of the volatile products to come off; and it is well known that this gas requires a high temperature for complete combustion.

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Dr. W. Pollard.

In two combustions made recently, there seemed some reason to suspect that methane had escaped combustion, as the difference between the carbon and hydrogen of the lower to the higher result gave the ratios of

$$C : H = 1 : 3{\cdot}5 \text{ and } 1 : 3{\cdot}8$$

whilst the ash in each case agreed.

On repeating these, concordant results with the higher value were obtained. Another source of error, when duplicates agree in the hydrogen but not in the carbon, may be due to all the carbon not being combusted, a little remaining with the ash. This has been found to occur on more than one occasion, in each case the coal having a high caking power and considerable ash (over 5%). It was owing to this that a boat 10cm. long is now used instead of one of the usual size, as the half-gramme of coal can be spread out into a very thin layer, thus reducing the chance of incomplete combustion. The following is an example of the error just described.

A boat 5cm. was used, and the caking power of the coal was about 45.

| | I. | II. | III. |
|---|---|---|---|
| C | 79·72 | 79·97 | 80·13 |
| H | 4·75 | 4·76 | 4·82 |
| Ash | 8·38 | 8·12 | 7·98 |

It will be seen that the hydrogens all agree to within ·1%, whilst the carbons are varying considerably. Nos. 2 and 3 are within the limit allowed of ·2%, but No. 1 is too low. On comparing the ashes, it is seen that the difference of Nos. 1 and 2 to 3 are ·40 and ·14 higher respectively, whilst the carbons of 1 and 2 are respectively

·41 and ·16.

Assuming the ash of No. 3 to be nearer the correct amount—the ash was nearly white, whilst 1 and 2 were grey—and subtract the ash of No. 3 from Nos. 1 and 2, adding the difference to the carbon, we get for the carbon

80·12 80·11 80·13.

It has been suggested that one cause of low carbon results might be due to some carbon monoxide escaping combustion to dioxide. At Mr. Seyler's suggestion, a small flask, containing a dilute solution of sodium palladium chloride, was placed behind the protecting **U**-tube, so that all gases escaping from the combustion and not previously absorbed by the **U**-tube and potash bulbs, must pass through this solution, and render it possible to detect monoxide. On no occasion has the solution been darkened, in spite of one or two low carbon determinations, which could only be explained—as the hydrogens and ashes agreed—by assuming a leak had occurred, although none had been detected, or from some other cause unknown.

One or two other possible causes of error in coal combustion may be briefly alluded to. The carbon percentage may be affected to a marked extent by the way in which moisture is determined. If the moisture value obtained by drying in vacuo

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over sulphuric acid more nearly represents the true moisture than the value obtained by drying at 105° for one hour, in certain cases the carbon may easily be a few tenths of a per cent. out. All coals analysed in this laboratory have moisture determinations done by both methods, but the value obtained by drying at 105° for one hour is exclusively used in calculating results, as this is the method more usually employed. The carbon, hydrogen, and ash are calculated first on the dry coal, and subsequently from these figures on to the "moist coarse" coal and dry ash and sulphur-free coal. The following example illustrates an error of the kind described:— Dr. W. Pollard.

| | |
|---|---|
| Moisture at 105° one hour | 2·17% |
| „ vacuo sulphuric acid | 2·47% |
| Carbon on dry coal | 82·80% |
| Calculated on to the "coarse moist" coal | |
| by moisture at 105° | 81·00% Carbon |
| by moisture in vacuo | 80·76% „ |

giving a difference of ·24% on the carbon, which is outside the limit within which duplicates should agree.

This may be an exceptional case, as such a large difference as ·3% in the moisture determined by the two methods is not often found. Where, however, coals rich in moisture have to be dealt with, it may be of importance to use both methods of moisture determination.

Two more sources of error will be just mentioned: first, the presence of carbonates in the coal, and, secondly, the error due to pyrites. A discussion on the latter will be found in the Report of the Coal Analysis Commission of the American Chemical Society *(loc. cit.)*.

In calculating the composition of coals in this laboratory no correction has been applied for either of these errors, as, in connection with the pyrites, it is impossible to say whether the sulphur may not, at any rate, partly be in combination in the coal.

*Caking Power.*—The platinum crucible used for this determination has the following dimensions:—

Diameter at top 42mm., at base 30mm.
Height 50mm. Capsule cover.

The coal is powdered to pass the 50-hole sieve; sand to pass the 40-hole and stay on the 50-hole sieve. The coal and sand are mixed in varying proportions, but so that the total weight of the two used for an experiment always is the same; 25 grammes being the weight used.

The charge having been placed in the crucible, it is heated exactly as for "volatile matter" determinations, allowed to cool, and when cold the cake is removed, placed on a flat surface, and a 500-gramme weight cautiously placed on the cake. When the cake *just* crushes the caking power is reached.

The caking power is expressed as the weight of sand required per weight of coal.

| | | | Sand. | Coal. |
|---|---|---|---|---|
| Thus: | Caking Power = | 4 | 20·0 | 5·0 |
| | | 9 | 22·5 | 2·5 |
| | | 24 | 24·0 | 1·0 |

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Dr. W. Pollard.

The test is a rough one, and not capable of great accuracy.

*Specific Gravity.*—Estimated on about 5 grammes of the sample specially set aside for this determination, in a specific gravity bottle. Air is removed by an air pump.

Moisture and ash determinations as made on this sample was to be able to correct to dry and dry ash-free coal.

The correction for ash is made by deducting ·01 from the specific gravity for each 1% of ash found.

The ash on this sample is determined in the muffle.

The results obtained are tabulated thus :—

PROXIMATE ANALYSIS.

| | | |
|---|---|---|
| Moisture<br>Volatile matter.<br>Fixed carbonaceous residue<br>Ash | } | Given on (1) moist coal ; (2) dry ash-free coal. |
| Total - - | | 100·00 |

ULTIMATE ANALYSIS.

| | | |
|---|---|---|
| Carbon<br>Hydrogen<br>Oxygen<br>Nitrogen<br>Combustible sulphur<br>Ash<br>Moisture | } | Given on (1) moist coal ; (2) dry coal ; and (3) dry, sulphur and ash-free coal. |
| Total - - | | 100·00 |

Sulphur in ash
Total sulphur
Caking power
Specific gravity

## ROTTENSTONE FROM SOUTH WALES.

The following analyses were made for Mr. Cantrill, to ascertain, if possible, what occurred in the conversion of the black limestone to Rottenstone.

For this purpose bulk analyses of the three samples were made, together with analyses of the residue obtained by treatment with dilute hydrochloric acid and boiling for about three minutes.

Samples of the residue from 1 were examined under the microscope, and found to contain minute cubes and apparently spheres of pyrites, the spheres may only be coated with pyrites.

A sample of the coarser constituents of 3 obtained by washing, by decantation with water, showed no cubes. Spheres were there, but of an iron-red colour, presumably due to ferric oxide from the oxidation of the pyrites. After this residue had been boiled with dilute acids, the spheres were no longer visible, the red colour had disappeared, and all that remained seemed to consist of a micaceous mineral and some cryptocrystalline silica.

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Dr. Flett has given the following description of the black limestone (sample 1):— Dr. W. Pollard.

E 3401. BLACK LIMESTONE S.W. OF CWM HAFFES, GLYN TAWE, TAWE VALLEY.

"A fine-grained dark limestone without organic structures, and consisting of small irregular grains of calcite, the surface of which are coated with brown films of limonite or organic matter or both. A few very small cubes of pyrites and flakes of colourless mica are the only visible impurities. There is no detrital quartz, and the silica shown in the analysis must exist as a thin framework of chalcedonic character between the calcite grains."

The following are the results obtained by analysis:—

1. Limestone which, on weathering, yields Rottenstone.
2. Inferior quality Rottenstone.
3. Best quality Rottenstone.

| | 1. | 2. | 3. |
|---|---|---|---|
| $SiO_2$ - - - | 16·50 | 70·87 | 80·82† |
| $TiO_2$ - - - | ·07 | ·55 | ·29 |
| $Al_2O_3$ - - - | 1·25 | 9·78 | 5·82 |
| $Fe_2O_3$* ‡ - - | ·50 | 4·61 | 3·79 |
| CaO - - - | 44·00 | 1·60 | 1·43 |
| MgO - - - | ·69 | 1·32 | ·88 |
| $CO_2$ - - - | 34·86 | ·27 | Not found |
| $P_2O_5$ - - - | ·36 | 1·39 | 1·36 |
| $FeS_2$‖ - - | ·32 | Not found | Not found |
| $Na_2O$ - - - | Trace | ·56 | ·30 |
| $K_2O$* - - | ·32 | 2·43 | 1·40 |
| $H_2O$ 105° - - | ·17 | 2·18 | 1·27 |
| $H_2O$ above 105° + Organic Matter | 1·31 | 4·62 | 2·82 |
| TOTAL - - | 100·35 | 100·18 | 100·18 |

* Traces of MnO and $Li_2O$ in all three.

† Less than 1% of colloid silica in No. 3.

‡ All Fe calculated as $Fe_2O_3$.

‖ S in 1 mostly as pyrites but probably a little pyrrhotite. All calculated as pyrites.



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Dr. W. Pollard.

The percentage of insoluble residue (prepared by boiling in dilute hydrochloric acid, etc., and igniting)

= 18·75 85·18 88·65

and the composition of these residues, expressed in percentage of the residue—

| | 1 | 2 | 3 |
|---|---|---|---|
| $SiO_2$ | 88·14 | 83·20 | 91·17 |
| $TiO_2$ | ·39 | ·64 | ·33 |
| $Al_2O_3$ | 6·75 | 10·36 | 6·01 |
| $Fe_2O_3$* | 2·58 | 1·92 | ·69 |
| CaO | ·12 | ·23 | ·65 |
| MgO | ·73 | ·89 | ·70 |
| $K_2O$ | 1.70 | Only estimated in bulk not in residue. | |
| $Na_2O$ | Trace.† | | |

* All iron calculated as $Fe_2O_3$. † = less than ·05 %.

The analysis of the second quality Rottenstone (No. 2) is not really comparable with Nos. 1 and 3. The much larger amount of alumina in the residue and the alkalies of the bulk, being so much higher than in No. 3, seem to point clearly to there being more clastic material (micaceous minerals are recognisable in all three samples under the microscope) than in the other specimens. It will, therefore, not be considered further in detail.

On the other hand, Nos. 1 and 3 are distinctly comparable. In the following table No. 1 has been re-calculated after elimination of all lime and carbonic acid, and as much magnesia as is required by the excess of carbonic acid; all moisture and organic matter and the pyrites calculated to $Fe_2O_3$. It should be remarked, in connection with No. 1, that no high accuracy can be placed on even the first decimal, as after elimination of the above-mentioned constituents (roughly 80%) the amount of original substance taken for analysis would be represented by about ·2 gramme.

In No. 3 lime, moisture and organic matter have been eliminated.

One hundred parts would therefore contain—

| | 1. | 3. | Difference. |
|---|---|---|---|
| $SiO_2$ | 84·03 | 85·47 | 1·44 |
| $TiO_2$ | ·36 | ·31 | ·05 |
| $Al_2O_3$ | 6·35 | 6·13 | ·22 |
| $Fe_2O_3$ | 3·61 | 4·00 | ·39 |
| MgO | 2·19 | ·93 | 1·26 |
| $P_2O_5$ | 1·83 | 1.41 | ·42 |
| $Na_2O$ | Trace. | ·32 | ·32 |
| $K_2O$ | 1·63 | 1·43 | ·20 |

From these figures it will be seen that Nos. 3 and 1 are almost identical.

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What has happened is that the carbonates have been extracted from the Limestone by weathering, leaving behind the siliceous matter which makes "Rottenstone." It is also clear that nothing has been introduced during the process of weathering, nor has anything, except the carbonates and sulphur, been removed. Dr. W. Pollard.

The value of the Rottenstone appears to be due to the high percentage of siliceous material in a fine state of division.

## WEATHERING OF MAGNESIAN LIMESTONE.

During the summer of 1899, whilst the Jermyn Street front of this Museum was being renovated, the opportunity was taken of collecting several specimens of the stone, to see how it had been affected by half a century of London atmosphere.* Owing, however, to more important work having to be attended to, it was not possible to complete the examination till recently. An interesting paper has appeared recently by Mr. E. G. Clayton, F.I.C., "On an Incrustation from the Stone Gallery of St. Paul's Cathedral." [*Proc. Chem. Soc.*, vol. xvii., p. 201 (1901).]

This paper is of great interest in connection with Portland stone in London atmosphere.

The report on the selection of stone for the Houses of Parliament [By Charles Barry, H. T. De la Beche, William Smith and Charles H. Smith. London: 1839] should be referred to, as it was a similar stone to the one recommended that was used in this Museum. The stone used here was from North Anston, Yorks, and its composition is given as—

| | | Upper Bed. | Fourth Bed. | Lower or Eighth Bed. |
|---|---|---|---|---|
| †1. | Calcium Carbonate | 52·0 | 52·5 | 52·8 |
| | Magnesium Carbonate | 45·2 | 44·7 | 44·4 |
| | Oxide of Iron and earthy matter | 2·0 | 2·1 | 2·1 |
| | Moisture | ·8 | ·7 | ·7 |
| | | 100·0 | 100·0 | 100·0 |

| | | | |
|---|---|---|---|
| 2. | Calcium Carbonate | 54·89 | 55·37 |
| | Magnesium Carbonate | 42·07 | 41·71 |
| | Protoxide of Iron | ·49 | ·73 |
| | Peroxide of Iron | ·24 | — |
| | Protoxide of Manganese | Trace | 1·68 |
| | Silica | ·56 | ·92 |
| | Water | ·51 | ·45 |
| | | 98·76 | 100·86 |

* The Museum was erected during 1848 to 1851. Sir James Pennithorne, Architect.

† 1. From "Lithology," by C. H. Smith, read at Royal Inst. Brit. Architects, April 29th and June 3rd, 1844. Analyst, R. Phillips, F.R.S.

‡ 2. G. F. Harris, "British Building Stones," from *The Builder*, Nov. 20th, 1886, p. 754. Analysts, Ransome and Cooper.



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Dr. W. Pollard.

From these analyses it will be seen that the stone is as near a true Dolomite as possible, the ratio of lime to magnesia (mean of these five analyses) being 1 : ·97.

The following are the main points observed in this examination. The stone facing S.W. was more weathered than that facing S.E., doubtless due to the S.W. winds being mostly wet, and to its being the prevailing wind (cf. Report, p. 4). It is impossible to give any exact figures as to the amount of stone which has been weathered, or has flaked off, but probably it is something between 1 and 3mm. This rough estimate was made possible by the fact that the stone contains occasional segregations of calcite crystals. These have stood the weather much better than the stone itself, and stood out wart fashion on the surface. Where the rain had fallen directly, the stone was rather less black than where it was sheltered. Only a trace of magnesium sulphate could be found on the exposed surfaces, whilst an appreciable amount was found where the stone was sheltered.

A microscopic section of a specimen that had been sheltered from the direct action of the rain was prepared, showing the surface in section, which Dr. Flett has described as follows:—

The following notes on the microscopic characters of specimens of the stone of which the Museum of Practical Geology is built, and of their weathered surfaces, are by Dr. J. S. Flett:—

The stone is a granular yellow dolomite consisting mostly of small rhombohedra, often rounded and slightly irregular in outline, but showing perfect crystalline form when occurring in cavities and veins. It contains many irregular-shaped pores, which are sometimes filled up with re-crystallised dolomite, and through the rock are scattered rounded patches, apparently concretionary. The blackened surface of the under part of the moulding from which the fragment was taken has been preserved, and is well seen in the section. It is covered with small crystals of gypsum, mostly in the form of monoclinic prisms and swallow-tailed twins. These form a layer mixed with black particles, probably sooty matter, and resting on a thin black film, beneath which the rock is unattacked. The average length of these crystals is about $\frac{1}{100}$ inch, and the thickness of the deposit, as preserved in the section, a little greater than this. Outside of the thin basal carbonaceous layer there is no dolomite, but only gypsum, which has, apparently, been formed by the evaporation of aqueous solutions of sulphate of lime, which have leached out of the stone. The black film upon the surface of the dolomite can be seen, where it is less opaque than usual, to consist of fibres of gypsum crossing irregularly and mixed with black particles, apparently carbonaceous.

This formation of calcium sulphate, or gypsum, on the surface of marbles and limestones in town is well known.

Sir A. Geikie has gone very thoroughly into this in connection with "Rock Weathering, Measured by the Decay of Tombstones" (*Geological Sketches at Home and Abroad*, MM. & Co., 1882, p. 182, and *Proc. Royal Soc. of Edinburgh*, 1880).

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In '*Geological Sketches*' a figure of the altered surface of a marble will be found, which had stood for eighty-seven years in Edinburgh. Dr. W. Pollard.

The black edge of gypsum and soot similar to that described by Dr. Flett in his account of the microscopic characters above, is very clearly shown.

In addition to this gypsum deposit on the stone of this museum, in one or two places sheltered from rain, small crystals, some as long as 3mm., were found. These occurred presumably where condensed moisture had evaporated. They were found to be magnesium sulphate.

What has occurred is that the sulphurous and sulphuric acids in the air have attacked the dolomite forming calcium and magnesium sulphates, and the latter being more soluble has to a great extent been leached out. This is entirely borne out by the following analysis. The sample was collected from the surface of the stone as scraped off by the masons in cleaning it. Hence a certain amount of unaltered stone is also in the sample.

The composition was found to be—

| | |
|---|---|
| Ignited insoluble residue | 5·2 |
| Oxides of Iron and Alumina | 1·4 |
| Lime | 26·9 |
| Magnesia | 9·5 |
| Sulphur Trioxide | 20·7 |
| Carbon Dioxide | 19·4 |
| Water lost at 105° | 1·8 |
| " " between 105° and 150° | 9·1 |
| Water above 150° + organic matter | 6·5 |
| | 100·5 |

If we assume the following molecules to be present (the magnesium sulphate was calculated from the amount of magnesia determined in a solution obtained by extracting with cold water) we get :- -

| | |
|---|---|
| $CaSO_4 2H_2O$ | 41·7 |
| $MgSO_4 7H_2O$ | 4·0 |
| $CaCO_3$ | 22·2 |
| $MgCO_3$ | 18·5 |
| *CaO | ·9 |
| *$(FeAl)_2O_3$ | 1·4 |
| Residue | 5·2 |
| Moisture and Organic Matter | 6·6 |
| | 100·5 |

Comparing this with the five analyses quoted above, it will be seen that the iron oxide and earthy matter has greatly increased, owing to the leaching out of lime and magnesium sulphates by the action of rain and fog.

---

* The CaO and $(FeAl)_2O_3$ uncombined here are possibly combined with the silica of the residue and with traces of Cl and $P_2O_5$.

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Dr. W. Pollard.

In conclusion it must be stated that the alteration of the stone surface is to a great extent due to chemical causes, owing to the presence of sulphurous and sulphuric acids in the London atmosphere. These decompose the dolomite giving sulphates of lime and magnesia. The sulphate of magnesia, being a soluble compound, is to a great extent leached out and washed away by rain. The sulphate of lime, being a sparingly soluble compound, is leached out to a far smaller extent and tends to form a coating (with the soot, etc.) which helps to protect the stone. No doubt flaking or scaling play an important part in the weathering as well, but it is not possible here to calculate to what extent.

Suffice it to say that, with the exception of a few blocks which were of inferior quality and hence had decomposed to a greater extent, considering the time and conditions to which the stone had been exposed, the state was by no means unsatisfactory.

## MINERALS FROM SKYE AND ROSS-SHIRE.

A black spinellid mineral, collected by Mr. Harker, was separated and analysed with the following results.

Mr. Harker gives the following account of its occurrence :—

"A black spinellid mineral from the peridotite group of the Cuillins. It occurs as small lustrous octahedra, making up practically the whole of certain seams, usually ½ to 1 inch thick, in the banded dunite of a small glen a little south of Allt a' Chaoich (the 'Mad Burn') near Loch Scavaig. The analysis shows it to be a Picotite. There are hitherto no analyses of this mineral from Britain."

| | | | | |
|---|---|---|---|---|
| $SiO_2$ | 1·19 | | | |
| $TiO_2$ | ·34 | | | |
| $Al_2O_3$ | 46·54 | ·4554 | | |
| $Fe_2O_3$ | 6·01 | ·0376 | ·6083 | |
| $Cr_2O_3$ | 17·55 | ·1153 | | |
| FeO | 10·10 | ·1403 | | |
| MnO | Trace | | | |
| (CoNi)O | ·24 | | ·6027 | |
| CaO | ·43 | ·0077 | | |
| MgO | 18·35 | ·4547 | | |
| Total | 100·75 | | | |

Omitting Silica, Titanic acid, Manganese and Oxides of Cobalt and Nickel, the ratio of RO : $R_2O_3$ works out to ·6027 : ·6083
or 1 : 1·01

The following is an analysis of the felspathic constituent of a Nepheline-Aegirine-Syenite-Pegmatite, a boulder from Coulmore, Ross-shire, collected by Mr. Hinxman.

*Portion of powder (separated by bromoform, diluted with xylene) of sp. gr. between 2·556 and 2·510.

* The powder was first treated with hydrochloric acid to remove nepheline.

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| | | Mol. Ratios. | Dr. W. Pollard. |
|---|---|---|---|
| $SiO_2$ | 63·84 | 1·0570 | |
| $Al_2O_3$ | 18·87 | ·1846 | |
| *$Fe_2O_3$ | ·68 | ·0042 | |
| CaO | ·18 | ·0032 | |
| $K_2O$ | 14·76 | ·1530 | |
| $Na_2O$ | 1·23 | ·0198 | |
| Loss on ignition | ·30 | | |
| Total | 99·86 | | |

* State of Oxidation not determined.

This would represent—

| | |
|---|---|
| $K_2Al_2Si_6O_{16}$ | 85·85 |
| $Na_2Al_2Si_6O_{16}$ | 10·43 |
| | 96·28 |
| Unaccounted for | 3·58 |
| | ·86 |

The portion unaccounted for being composed of—

$SiO_2$ 1·22 $Al_2O_3$ 1·20 $Fe_2O_3$ ·68 CaO ·18
Loss on ignition ·30

## TERTIARY IGNEOUS ROCKS FROM SKYE.

Three more Tertiary igneous rocks from Skye have been analysed. They were collected by Mr. Harker, who furnishes the following descriptions of them :— Mr. Harker.

8062 is an example of the innumerable sheets of basic rock referred to in former reports as cutting in an inclined direction the gabbro of the Cuillin Hills. It is a normal dolerite, bearing no close resemblance in composition to the gabbro. The locality of the specimen is Loch a' Bhàsteir.

9250 and 8732. Two closely associated rocks, forming one of a group of composite intrusions at Druim na Crìche, five and a half miles N.W. of Sligachan.

Each of these intrusions consist of two laccolitic masses in contact with one another ; the upper of an olivine dolerite (9250) with large porphyritic crystals of labradorite, the lower of a peculiar rock (8732) of more compact texture, which may be styled olivine andesite, its principal constituent minerals being oligoclase and olivine.

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Dr. W. Pollard.

The analyses are as follows :—

| | 8062 | 9250 | 8732 |
|---|---|---|---|
| $SiO_2$ - - | 47·64 | 50·33 | 49·24 |
| $TiO_2$ - - | 1·27 | 1·81 | 1·84 |
| $Al_2O_3$ - - | 14·16 | 19·97 | 15·84 |
| $Fe_2O_3$ - - | 5·18 | 2·81 | 6·09 |
| $Cr_2O_3$ - - | Trace | Trace | Trace |
| FeO - - | 7·96 | 6·23 | 7·18 |
| MnO - - | ·33 | ·17 | ·29 |
| (CoNi)O - - | Trace | Trace? | Trace |
| CaO - - | 11·71 | 8·03 | 5·26 |
| BaO - - | Not found | ·06 | ·09 |
| SrO - - | Not looked for | Trace | Trace |
| MgO - - | 7·38 | 3·24 | 3·02 |
| $K_2O$ - - | ·71 | 1·19 | 2·10 |
| $Na^2O$ - - | 2·38 | 4·30 | 5·21 |
| $P_2O_5$ - - | ·09 | ·17 | 1·47 |
| F - - - | Not looked for | Not looked for | ·18 |
| S - - - | ·03 | Not found | ·03 |
| $H_2O$ at 105° | ·19 | ·87 | 1·08 |
| $H_2O$ above 105° | 1·44 | ·99 | 1·61 |
| Total. | 100·47 | 100·17 | 100·53 |
| | | Less O for F | ·07 |
| | | | 100·46 |

## ROCK FROM NEWLYN, CORNWALL.

Dr. Flett.

The following specimen, E3424, was collected by Mr. Clement Reid. The locality given is "Gwavas Quarry, near Newlyn Cornwall, 1″ 358, 6″ 74 S.W. Thick Sill (about 80′). Specimen from near the middle of the sill, and from the centre of a newly-broken block." Dr. Flett has examined the slice and gives the following description :—

E.3424. Gwavas Quarry, Newlyn, Cornwall.

Under the microscope this rock consists of actinolitic and tufted hornblende in small radiate groups of green needles, rather strongly pleochroic, and felspar, mostly plagioclase, but partly also untwinned alkali felspar. Much of the felspar is in large fairly idiomorphic crystals surrounded by smaller grains of irregular shape, so that the rock has a distinctly porphyritic character. According to the angles of symmetrical extinction the plagioclase is mostly an acid andesine. Grains of untwinned or simply twinned felspar (orthoclase or albite) are frequent in the groundmass surrounding the phenocrysts. In the larger nests and patches of actinolite there is a small amount of water-clear untwinned or simply twinned felspar which is probably albite. Iron oxides, leucoxene, and a few scales of biotite are the other ingredients. The actinolite may be regarded as having all formed from pyroxene, though no trace of the original outlines of this mineral can be found, and the clear albite appears also to be of new formation.

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Dr. Flett. The analysis shows that the rock belongs really to the augite andesites or augite porphyrites. It contains too much silica and alkalies, too little lime and magnesia for a diabase. Even if all the lime is supposed to be present in the felspar (which cannot be the case as some is required for the actinolite) the ratio of lime to soda 3·71 to 6·52 would indicate a felspar of the oligoclase group. The original plagioclase is probably somewhat more basic than this (andesine), the rest of the soda being taken up in the albite and to a small extent in the orthoclase.

Sp. gr. 2·80 at 19°.

Dr. W. Pollard.

| | |
|---|---|
| $SiO_2$ | 59·84 |
| $TiO_2$ | ·64 |
| $Al_2O_3$ | 15·71 |
| $Fe_2O_3$ | 1·68 |
| FeO | 7·03 |
| MnO | ·12 |
| CaO | 3·71 |
| MgO | 1·37 |
| $K_2O$ | 2·76 |
| $Na_2O$ | 6·52 |
| S | ·10 |
| $P_2O_5$ | ·20 |
| $H_2O$ 105° | ·14 |
| $H_2O$ above 105° | ·31 |
| Total | 100·13 |

BaO and $Li_2O$ not found.

## PSEUDOGAYLUSSITE FROM THE CLYDE.

Dr. Flett. Note on Crystals from the Clyde, analysed by Dr. Pollard.*

These crystals were obtained a few years ago by a dredging steamer engaged in deepening the channel of the Clyde near Helensburgh. They are dark brown in colour, resinous, transparent only in thin splinters, with a yellow streak and powder, no cleavage, and hardness about 3. The commonest are long prisms pointed at both ends, but without crystalline faces. The largest measures 5½ by ¾ inch. In transverse section these prisms are squarish or rhombic, but the angles vary considerably, and the roughness and rounded character of the faces do not allow of accurate measurements. On the best specimens small triangular facets cover the surfaces, their apices being directed from the edges towards the centres of the faces. The analyses show that they are impure carbonate of lime, the colouring matter being apparently organic, and the low specific gravity a consequence of a slightly porous structure. Microscopic sections showed that they have a distinctly zonal structure, and consist of little spherulites of fibrous calcite with occasional layers of parallel fibres between the spherulites and on the surface of the crystals.†

* Extracted from a paper read by Dr. Flett at the meeting of the British Association at Glasgow, September, 1901.

† For a full description of these crystals with an analysis, *see* Ch. O. Trechmann, "Ueber einen Fund von Ausgezeichneten Pseudogaylussit (=Thinolith=Jarrowit) Krystallen." *Zeitschrift für Krystallographie* xxxv., 1901.

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Dr. Flett. Another mode of occurrence is in groups radiating from a centre. These may consist of as many as 40 or 50 individuals The component crystals are smaller than in the previous cases, and have the barleycorn form of the well-known pseudogaylussite from Sangerhausen. The surface markings are similar to those described, but often the surface is honeycombed as if by corrosion. For specimens of these I am indebted to Mr. Renwick, Secretary of the Glasgow Geological Society.

Crystals of pseudogaylussite were obtained in excavations for the Jarrow Docks in 1857, and have been described by Professor Miers under the name of Jarrowite.* He agrees with Descloiseaux, Williams, and Dana that they are in all probability pseudomorphs after celestite. In this case tests for barium and strontium gave negative results, and a large clay nodule full of these crystals, forwarded by Mr. Renwick, proved to consist of carbonates of lime and iron mixed with clay, and did not contain strontium in determinable quantity.

Dr. W. Pollard. The crystals (from the Clyde) of pseudogaylussite which were analysed in this laboratory were sent to Mr. Rudler by Mr. John Paton, of Glasgow.

The analysis gave the following values:—

| | | |
|---|---|---|
| CaO | 47·93 | |
| MgO | 4·21 | |
| $CO_2$ | 39·91 | |
| $P_2O_5$ | 2·23 | |
| Loss at 105° | 3·13 | |
| Loss above 105° (to ignition) | 2·81 | = Water and organic matter. |
| Residue insol. dil. HCl. | ·11 | |
| | 100·33 | |

Traces of iron, manganese, chlorine, and sulphate also found.

No nitrogen found. Carbon of organic matter about 1·2%. Calculating as carbonates and phosphates,

| | | |
|---|---|---|
| $Ca_3(PO_4)_2$ | 4·87 | |
| $CaCO_3$ | 80·88 | |
| $MgCO_3$ | 8·28 | |
| MgO | ·25 | not accounted for. |
| | 94·28 | |

The specific gravity was found to be

On a crystal fragment 2·55
Powder in pyknometer 2·57 } at 23°

Dr. C. O. Trechmann [*Zeitschrift für Krystallographie*, xxxv., p. 283, 1901] found

2·575 at 18·5° C. in coarse powder,
2·602 at 16·5° C. in fine powder,

for some crystals from the same locality.

* "On some British Pseudomorphs," by Prof. H. A. Miers, *Mineralogical Magazine*, 1897, xi., p. 264.

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The composition of these are quoted below, for comparison with those analysed here:— Dr. W. Pollard.

| | Dr. C. O. Trechmann. | M.P.G. |
|---|---|---|
| $Ca_3(PO_4)_2$ - - - | 5·52 | 4·87 |
| $CaCO_3$ - - - - | 83·52 | 80·88 |
| $MgCO_3$ - - - - | 9·03 | 8·28 |

This appears to show that the composition of the different crystals may vary, but the agreement is as close as may reasonably be expected in the case of pseudomorphs of this nature.

## IV. PALÆONTOLOGICAL WORK.

The ordinary duties of the Palæontological Department in relation to the maintenance of the collection of fossils in the Museum of Practical Geology, and the detailed work necessitated in the registration and determination of the fossils received from the officers in the field and otherwise, although making the first, and a large, demand upon the time of the officers, call for little notice in this place. Some 800 new specimens have been added to the collection already in the Museum, and a large amount of revision has been accomplished, necessitating in some instances a rearrangement of the cases. Mr. E. T. Newton.

The large series of Echinodermata and Phyllocarida from Palæozoic formations, and the plants from the Inferior Oolite and other Jurassic strata, have been revised by Mr. H. A. Allen, who has taken advantage of this opportunity to prepare a catalogue of all the figured and type specimens in the first two of these groups, which this institution possesses, thus continuing the very useful piece of work begun some two years ago (*see* Appendix, p. 200). A similar catalogue of the Pliocene and Pleistocene figured specimens was prepared by the same officer early in the year, but, being ready, it was deemed expedient to publish it in the Appendix of the *Summary of Progress* for 1900.

The Carboniferous Cephalopoda, contained in the Museum cases, have undergone a similar revision by Dr. F. L. Kitchin, whose time has been largely occupied during this year with the determination of the large series of fossils collected by Mr. G. W. Lamplugh from the trial borings at Brabourne and Penshurst, as well as from the shaft at Dover. Dr. Kitchin has paid several visits to Dover in order to watch the progress of the shaft being sunk through the Jurassic strata, and has himself obtained representative collections of the fossils from the various horizons passed through.

The examination of the Devonian fossils collected by Mr. W. A. E. Ussher, and mentioned in last year's *Summary of Progress*, has been completed, and a preliminary report prepared. The occurrence at certain localities in the neighbourhood of Looe, and at other places in the Torquay promontory, of such fossils

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Mr. E. T. Newton.

as *Spirifera primæva*, *Orthotetes hipparionyx*, and *Pleurodictyum problematicum*, and the further recognition at still other places of *Strophomena latecosta* (= *Tropidoleptus rhenanus*), *Rensselæria strigiceps*, *Orthotetes hipparionyx*, and *Homalonotus*, seem to demonstrate that the Looe fauna occurs in the Torquay promontory. Certain of the characteristic fossils are likewise met with in the intermediate area. The fragmentary nature of the fossils makes the determination of the horizons somewhat uncertain; but Mr. Ussher has hopes of being able, by their means, to correlate the Devonian horizons in a large part of this difficult and disturbed district.

Three or four small sets of fossils were received from Mr. G. Barrow, from the promontory of Suishnish, between Loch Slapin and Loch Eishort, south of Broadford, Skye, where he was anxious to trace the upper limits of the Lower Lias, and possibly the base of the Middle Lias; but all the determinable fossils pointed to the beds belonging to the zone of *Ammonites Jamesoni*, and there was nothing that could be clearly referred to the Middle Lias at this locality.

A series of specimens of Cherts and other rocks from Alt nan Leac, Soay Sound, South Skye, have been examined; these were forwarded by Mr. C. T. Clough, who thought they might be of Cretaceous age. Some of the Cherts had been found *in situ*, others in the volcanic agglomerate of the district; and they resemble in appearance certain of those which had been discovered in Arran. Several slices were prepared, which showed, in the first place, that the rock *in situ* was similar to that in the agglomerate. In all these Cherts organisms are present, but they are much obscured by chalcedonic deposits. Sponge spicules seem to have been very abundant, but have become decomposed. Foraminifera are present, Textularian forms being most numerous, but *Globigerina* seems also to be represented. Some of the sections show fragments of Echinoderm plates and pieces of Serpula. These Cherts are unlike those from Arran, but support Mr. Clough's opinion of their Cretaceous age; it is thought, however, that these rocks have more the appearance of Greensand Cherts than of altered Chalk—an opinion which Dr. G. J. Hinde has been good enough to confirm.

A series of plants, collected some years ago from the Reading Beds in the Waterloo Brickyard, Reading, have been recently re-examined for the purposes of the Memoir on this district, written by the late J. H. Blake, and now being prepared for publication by Mr. H. W. Monckton. The following forms are believed to be present, but their determination can only be taken as approximately correct:—*Anemia subcretacea*, *Acer* sp., *Aralia* near to *looziana*, and *Laurus* resembling *L. Jovis*. There are likewise slender leaves like *Salix;* the base of a leaf like *Litsaea;* and a fragment with venation like *Viburnum*.

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Mr. E. T. Newton.

The following is a list of the specimens in the Museum of Practical Geology, figures of which have been published during the year:—

*Palæontographical Society's* volume for 1901 :—

By Miss Elles and Miss Wood :

*Didymograptus hirundo*, Salter.
„ *v-fractus* var, *volucer*, H. A. Nicholson.
„ *gibberulus*, Nicholson.
„ *deflexus*, n. sp.
„ *nanus*, Lapworth.

By Dr. Wheelton Hind :

*Leiopteria Thompsoni*, Portlock. Four specimens.
*Actinopteria persulcata*, McCoy. Three specimens.
*Pteronites latus*, McCoy.
*Posidonomya Becheri*, Bronn. Three specimens.

By R. H. Traquair :

*Elonichthys Aitkeni*, Traquair.

By H. Woods :

*Trigonia scapha*, Agassiz.
*Spondylus striatus*, Sowerby.
„ *dutempleanus*, d'Orbigny.
*Plicatula placunea*, Lamarck.

*Geological Magazine* for 1901 :—

By H. A. Allen :

*Fouquea cambrensis*, n. sp.

## V. MUSEUM OF PRACTICAL GEOLOGY.

Mr. F. W. Rudler.

Among the most notable donations is a large collection of polished Indian Agates, presented in the early part of the year by Mr. Lennox Boyd. Attention may also be called to a series of minerals from Victoria, presented by the Department of Mines through the Agent-General.

In view of the removal of the offices of the Geological Survey, on the expiration of the tenure of the adjacent premises in Jermyn Street in the course of the present year, measures have been taken to provide for the accommodation of the officers of the Survey in the Museum building. This has necessitated considerable alterations in the arrangement of the Museum. The collections of Pottery, Porcelain, Glass, Enamels and Mosaics have been removed, partly to the Victoria and Albert Museum at South Kensington, and partly to the Branch Museum at Bethnal Green. The space thus gained is being fitted up as a Petrographical Department, to which the rock specimens at present exhibited in a room on the Upper Gallery of the Museum, will shortly be transferred.

The contents of the two Model Rooms have also been removed, and such of the models as illustrate British Geology are now exhibited on the principal floor of the Museum, where space has been obtained for their display by the removal, to the Alexandra

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Mr. F. W Rudler.

Palace, of several cases of specimens illustrating the application of metals to various purposes of industry and art.

The Library has received many valuable additions during the year, and the collection of Geological Photographs has also been largely augmented. An extensive collection of the Maps and Sections of the Geological Survey of Great Britain and Ireland has been transferred from the Survey Office to the Library, where visitors desirous of consulting them will find them more convenient of access. Progress has been made in the work of removing from the Library those works which are not strictly Geological in character; and during the past year upwards of 7,000 volumes have been transferred to the Science Library of the Victoria and Albert Museum.

## VI. MAPS, SECTIONS, AND MEMOIRS PREPARED AND PUBLISHED.

The following is a List of the Maps, Sections, and Memoirs issued by the Geological Survey of England and Wales during the past year:—

### I.—MAPS.

*One-inch Maps (New Series).*

Sheets 261 and 262 (Bridgend), in one map. Two editions, with and without Drift. By R. H. TIDDEMAN and T. C. CANTRILL.

*One-inch to four miles (Index) Map.*

*New Editions.*

Sheets 8 and 11 revised. Sheet 12 reprinted.

*Six-inch Reference Maps.*

49 MS. coloured copies of six-inch sheets and quarter-sheets have been made from the field copies, and deposited in the Office for public reference. These are as follows:—

Berks.—9 N.W., N.E., S.W., S.E.; 16 S.W.
Brecon.—37 N.W., S.W.
Bucks.—41 N.E., S.W., S.E.; 46 N.W., N.E., S.W., S.E.
Carmarthen.—35 S.W.; 42 N.E., S.E.; 43 N.W., S.W.
Dorset.—21 S.E.; 31 S.W.; 40 S.W.
Glamorgan.—7 S.E.; 8; 14 N.E.; 15; 24.
Leicester.—18 N.W., N.E.; 19 S.W.; 27 S.W.; 33 N.E.; 38 N.E.
Oxford.—40 N.W., N.E., S.W., S.E.; 45 N.W., N.E., S.W., S.E.; 46 N.W., N.E., S.W., S.E.; 50 N.W., S.W.
Rutland.—4 N.E.
Wilts.—69.

### II.—VERTICAL SECTIONS.

Three Sheets of Vertical Sections have been published.

Sheets 84 and 85 of Shafts in the South Wales Coalfield.
Sheet 86 of Shafts in the North Staffordshire Coalfield.

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### III.—MEMOIRS.

Summary of Progress of the Geological Survey of the United Kingdom" for 1900, pp. 221. Price 1s.

"Guide to the Geology of London." By W. WHITAKER. 6th edition. pp. 102. Price 1s.

*List of Extra-official Publications.*

ALLEN, H. A.—"On an Insect from the Coal-Measures of South Wales." *Geol. Mag.*, 1901, pp. 65–68.

GIBSON, W.—"On the Character of the Upper Coal-Measures of North Staffordshire, Denbighshire, South Staffordshire, and Nottinghamshire; and their Relation to the Productive Series." *Quart. Journ. Geol. Soc.*, vol. lvii., pp. 251–265.

HILL, J. B.—"On some Geological Structures in West Cornwall' *Trans Royal Geol. Soc. Cornwall*, vol. xii., part vi.

NEWTON, E. T.—"British Pleistocene Fishes." *Geol. Mag.*, 1901. pp. 49–52.

————"Graptolites from Peru." *Geol. Mag.*, 1901, pp. 195–197.

STRAHAN, A.—"On the Passage of a Seam of Coal into a Seam of Dolomite." *Quart. Journ. Geol. Soc.*, vol. lvii., pp. 297–304.

————"An Abnormal Section of Chloritic Marl at Mupe Bay, Dorset. *Geol. Mag.*, 1901, pp. 319–321.

TIDDEMAN, R. H.—"On the Formation of Reef Knolls." *Geol. Mag.*, 1901, pp. 20–23.

USSHER, W. A. E.—"The Culm-measure types of Great Britain." *Trans. Inst. Mining Engineers*, vol. xvii.

WEDD, C. B.—"On the Corallian Rocks of St. Ives (Huntingdonshire) and Elsworth." *Quart Journ. Geol. Soc.*, vol. lvii., pp. 73–83.

WOODWARD, H. B.—"Note on a Phosphatic Layer at the Base of the Inferior Oolite in Skye." (*Brit. Assoc.*) *Geol. Mag.*, 1901, pp. 519, 520.

## II. SCOTLAND.

### I. FIELD WORK.

Dr. Horne reports that in the northern district in charge of Mr. Gunn the work of the survey has been continued in the northern part of Inverness-shire and in the central and eastern parts of Ross-shire, as well as in a small portion of the county of Sutherland. Work was carried on in one-inch sheets 61, 71, 72, 83, 92, 93 and 102, and of these 71 and 92 are reported as completely surveyed.

#### 1. NORTHERN DISTRICT—INVERNESS-SHIRE, ROSS-SHIRE AND SUTHERLANDSHIRE.

Mr. W. Gunn, District Geologist.

Mr. C. T. Clough
Mr. L. W. Hinxman
Dr. C. B. Crampton
} Geologists.

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The location of the staff was as follows:—

Mr. Clough worked in the parish of Glenelg in the western part of Inverness-shire: Mr. Hinxman in the Inverlael Forest and near Loch Garve in central Ross-shire, and in the northern part of Inverness-shire: Dr. Crampton in the Strathvaich and Inverlael Forests in central Ross-shire, and in the Strathrusdale district of East Ross-shire: Mr. Gunn in the Fannich and Strathvaich Forests of central Ross, in the Loch Broom district of the same county, and on the shores of the Dornoch Firth. The Assistant Director, Dr. Horne, completed the survey of some small portions of ground in the Fannich Forest.

## METAMORPHIC ROCKS.

Mr. Clough.

Mr. Clough's work on the oldest rocks lay in two detached districts: (1) between the S.E. side of Loch Duich and the head of Glenelg; (2) near Inverguseran.

*Glenelg.*—In district (1) the oldest rocks belong to the Lewisian gneiss formation and the Moine schists. Among the members of the first formation were found marble, garnetiferous kyanite, biotite schist, hornblende schist, eclogite, and serpentine. Biotite schist forms most of the area between Balvraid and Loch Iain Mhic Aonghais. It is supposed to be an altered sediment of approximately the same age as the limestone, and it differs from the micaceous schist of the Moine formation in the same neighbourhood in various respects, particularly in containing thin streaks and lenticles of dark hornblende schist, and granulitic pale-grey quartz-felspar material, which has, perhaps, been formed from old pegmatites.

The Moine rocks occupy a considerably larger area than that of the Lewisian gneiss. In respect of composition they are generally divisible into two classes, one of more siliceous character than the other; but there are rocks of intermediate type, and it is not clear that all the rocks of one type are on one horizon.

The bands next to the Lewisian gneiss are in some places of the siliceous and in others of the more micaceous type. On the E. slope of Beinn Aoidhdailean is a thin strip of Lewisian gneiss, at the W. margin of which the Moine rocks are generally of the micaceous type; while on the E. margin, for about a mile along the strike, there is a band of siliceous schist. The phenomena might give the impression that we have here an unfolded succession of three rocks, in which the Lewisian gneiss occupies the middle position. It is, however, more probable that the gneiss occurs in the middle of a long-limbed isocline. The difference in the characters of the beds on either side now seems startling in view of the short distance between them, but we must remember that this distance may be much less than that which once separated the areas of formation of the beds. It has often been noticed, also, that as we follow some straight junction-line between the Moine rocks and the Lewisian gneiss, both these rocks vary considerably in character.

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Mr. Clough.

The Moine rocks show different stages of alteration in different districts. In many places they are represented by veined gneisses, in which half of the rock is composed of thin lenticles and streaks of pegmatite, while in the other half the minerals developed are unusually large. Veined gneisses, partly of a siliceous and partly of a micaceous type, are well seen in the following places: between Strath Chomair and Biod an Fhithich, at the Creagan Dubh of Ghleann Aoidhdailean, the top of Sgurr Mhic Bharraich, and on the watershed extending S. of this hill for two miles or so. Besides the thin pegmatites above referred to, which are repeatedly folded with the beds, there are, in certain areas in which the rock is not always veined with thin pegmatites, many thick, well-defined bands of pegmatite, as much as 50 yards broad, which cross both the Lewisian gneiss and the Moine rocks. These bands are later than the thin folded pegmatites, and they often cross quartz veins and beds which have previously been intensely folded. In one locality some of the bands have been sheared and partly granulitised.

After the Lewisian gneiss and the Moine rocks had been invaded by pegmatites and folded, they were pierced by a series of intrusive rocks, which we may call the Glenelg-Ratagan complex.* The largest outcrop of these rocks extends from near Suardalan rather more than three miles in a N.N.E. direction, and the average breadth is two miles. Wherever they are seen, the outer margins of the main mass and the minor outcrops are very jagged, and formed of rocks which are quite unchilled.

In the field the rocks can be roughly divided into three groups, each of which includes several varieties, that seem to pass into one another, and in certain places the rocks of one group also pass gradually into those of another. The groups are as follows:—

A. Biotite granite (or granitite), biotite hornblende granite, pale syenite.

B. Dark syenite, augite syenite, mica augite diorite.

C. Pyroxenite, biotite pyroxenite, hornblendite.

The rocks of the ultrabasic group C. contain a small proportion of orthoclase. The syenite in group A. contains a very small proportion of the ferromagnesian constituents, and a little quartz.

On the W. side of the complex there is a granite, which passes gradually eastwards through Tonalite into Diorite, but farther E. the rocks of group A., including a granite of somewhat different character from that at the W. side, often intrude into, and include portions of rocks in group B. In one place rocks of group B. clearly intrude into others of group C., and we infer that they often do so from the numerous inclusions of pyroxenite, &c., they contain.

The dark syenites and diorites often show flow structures, and sometimes have such a prominent banding that they might be

* The E. portion of this complex has not yet been surveyed.



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Mr. Clough. taken for Lewisian gneisses. Short strings of granite or granite porphyry, irregular in direction and without chilled margins, frequently cross the banding.

The rocks of groups A. and B. are in some places sheared in thin nearly vertical bands, which have been thoroughly granulitised. These are never more than a few feet thick, but in some places, *e.g*, on the coast half a mile N.W. of Ratagan, they are so crowded that they form a considerable proportion of the rock.

In and near the complex there are some dark basic dykes, which are foliated and cut by strings of granite porphyry. One of these dykes is called by Dr. Flett a mica diorite. A considerable number of unfoliated dykes, including quartz felsites, porphyrites and mica traps, pass through rocks of the complex, and have thoroughly chilled margins. Their general direction is W.N.W.

(2).—*Inverguseran.*—In this district nearly all the rocks belong to the Moine series, but near Rudh' Ard Slisneach there are also small patches which may be grouped with the Lewisian gneiss.

In no place have the Moine rocks been converted into veined gneisses, but many of them, especially the more micaceous, are crowded with small spots, usually from $\frac{1}{8}$ to $\frac{1}{16}$ inch in diameter, of secondary felspar, apparently albite. A broad zone of garnetiferous mica-schist, which is well exposed on the coast near and S. of the village of Airor, contains a good many impure calcareous lenticles and thin calcareous beds, rarely more than a few inches thick, which still show clastic grains more than half an inch long, chiefly of quartz. The zone has a considerable resemblance to the Loch na Dal series,* but is in a much more altered condition.

The igneous rocks are all dykes, and later than the period of foliation and folding of the schists. They may be divided into three groups—

1. Diorite.
2. Mica traps and lamprophyres.
3. Rocks of Tertiary age. (These are described elsewhere, *see* p. 114.)

The two first groups are of small extent and their relations are doubtful. The general direction of the dykes of group 2 is nearly E. and W.

*Physical and Economic Features of the Glenelg Districts.*—The area surveyed near Loch Duich and in Glenelg is for the most part of a wild hilly character, but the igneous complex already described forms an exceptionally green smooth tract, and a considerable part of it is said to have been under the plough about 80 or 90 years ago. Most of the rocks of the igneous complex disintegrate readily, and give rise to soils which are presumed to be rich in alkalies, and perhaps also in apatite—a mineral which is a noticeable macroscopic constituent of the rocks.

* The lowest series but one of the Torridonian rocks of Skye,

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Near the head of the Glenbeg of Glenelg there is a vein of galena, about four inches broad, but it is only seen in the stream-bed. Mr. Clough.

The largest peat moss, occupying perhaps a quarter of a square mile, lies about three-quarters of a mile W. of Suardalan, but being some distance off any house, it is not cut for fuel. Most of the shepherds have peat near their own homes, which is generally of excellent quality, though sometimes in small patches. In a peat moss rather more than half a mile N.W. of Bealachachasain there is a sulphur well, which once had considerable fame, but it is not so strong as formerly.

All the hill ground is pastoral, but on the side of Loch Duich, and near some of the houses, there are a few ploughed fields. The population is very sparse, and the ruins of several crofter hamlets are noticeable in the Glenmore of Glenelg. Near Inverguseran the 100-feet raised beach was formerly under cultivation, both along the shore and in the glen, and a small part of the same beach is still cultivated near Airor. The gravel in the present and the 20-feet raised beach near Inverguseran is very clean, and the pebbles in it are for the most part hard and siliceous. It is occasionally shipped for use in gardens in more populous districts.

With the exception of five isolated houses, most of them occupied by shepherds or keepers, the population is confined to the picturesque hamlet of Airor. There is a good natural harbour here, and the people make their living partly by fishing.

*Fannich Forest.*—In the autumn Mr. Horne completed the small patches of unsurveyed ground at the head of Loch Fannich, Ross-shire.

Part of this area lies to the north of Loch Fannich and along the south side of the Fannich watershed, extending from A'Chailleach (3,276 feet) by Sgurr Breac to Sgurr nan Clach Geala (3,581 feet). The various groups of crystalline schists identified and traced by Mr. Gunn on the N. side of the Fannich mountains (*Summary of Progress*, 1897, p. 38; 1899, p. 10) have been followed southwards to Loch Fannich and the hills beyond. A description of the geological structure of the south portion of the Fannich group, so far as the lines had then been traced by Mr. Horne, appeared in the *Annual Summary*, 1898, p. 11, and 1899, p. 8. In the latter Report (pp. 8 and 9) reference is made to the occurrence of a belt of acid gneiss with basic bands and lenticles of epidiorite and hornblende schist, resembling certain types of Lewisian gneiss, which belt, in the western part of the Fannich group is both underlain and overlain by garnetiferous muscovite-biotite schist. During last autumn the boundaries of this belt were traced from the watershed between Sgurr Breac and Sgurr nan Clach Geala southwards by Torran Ruadh to near the north shore of Loch Fannich, and westwards by the mouth of Allt nah-Ara, 1¼ miles east of Cabuie, towards the Nest River (Abhuinn Nid). Along the line of junction with the underlying and overlying muscovite-biotite schist, where there probably was considerable differential move- Dr. Horne.



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Dr. Horne. ment, the acid gneiss shows marked linear foliation, with "eyes" of felspar, and resembles the granulitic schists of the Moine type. In places, however, it is coarsely granulitic, highly quartzose, with muscovite and biotite. The distinctive feature of the belt is the presence of basic bands, sometimes massive with hornblende and plagioclase felspar, and sometimes foliated, which transgress the foliation planes of the acid gneiss. One of these has been traced for a third of a mile on the south slope of Creag nah-Ara east of the head of Loch Fannich, and another for half a mile southwards, from the head of Allt Leac a' Bhealaich.

The muscovite-biotite gneiss with thin pegmatites and lenticles of garnetiferous hornblende rock that overlies the belt of acid gneiss just described, forms the crest and south slopes of A'Chailleach and of Sgurr Breac; it is exposed in Allt Leac a' Bhealaich and is continued southwards in Sail Mhor to Creag nah-Ara near the head of Loch Fannich. An examination of the crags on the south slope of Sgurr Breac and also on Sail Mhor reveals the puckering and overfolding of the muscovite-biotite gneiss.

Another patch of ground completed in the autumn lies about three miles to the west of the head of Loch Fannich and to the north of the Cabuie River, where the rocks consist of granulitic quartzose schists of the Moine type with a zone of biotite schists. The latter has been traced from the watershed at the head of Allt a' Chleibh southwards to the Cabuie River, and is probably the western prolongation of the Sgurr Mòr Fannich band.

Mr. Gunn. The small area completed by Mr. Gunn in the Fannich Forest lies mainly on the south and east sides of Beinn Liath Mhòr Fannaich, and the ground is nearly all above the 2,000 feet contour. The schists of this area are of the usual quartzose Moine type, with occasional thin bands of biotite schist. These rocks are bounded on the west by the thick mass of biotite schist which forms Sgurr Mòr. The rocks are intensely folded, the axis of the folds trending beween north-west and north, and the dip of the folds being to the west. This is the structure of the southern inclination of the part of the area adjoining Abhuinn a' Ghiubhais Li', but as we follow the rocks northward the folds become vertical, or nearly so, and strike due north, the strike gradually trending to the east of north, and the steep-sided folds dipping easterly.

Mr. Hinxman *Ross-shire.*—The ground between Loch Garve and Strathconon (Sheet 83), on which Mr. Hinxman was engaged during the month of April, is for the most part bare and rocky, and the geological structure extremely complicated. The siliceous Moine schists and the coarse muscovite biotite gneiss by which the ground is chiefly occupied are interfolded in a most intricate manner; while between Tarvie and Strathconon there is, in addition, a great development of garnet-amphibolite, an intrusive rock which shares in the folding of the schists.

The basic rock occurs in more or less continuous sills and lenticular masses. These are thoroughly foliated with the schists, but are usually coarser and more felspathic in their central portions. Near the edge of one of these intrusions at

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Comrie, where the mass is upwards of 300 yards in breadth, a thin band of ferriferous calc-biotite schist occurs, apparently along a line of crush. The edge of this sill shows a somewhat unusual modification of the igneous rock, probably due to the absorption of material from the contiguous schists. It contains, according to Dr. Flett, a little quartz and orthoclase in addition to the usual biotite and plagioclase, besides large masses of ferriferous carbonates, and plates of iron oxide. Crush lines are also frequent in the Moine schists, and are sometimes accompanied by bands of breccia two or three feet in breadth, made up of angular fragments of the adjacent rock. Mr. Hinxman

*Inverness-shire.*—The area between Glen Strathfarrar and Glen Cannich, surveyed during the summer and late autumn months, is entirely occupied by schists and flagstones of "Moine" type, and garnetiferous muscovite biotite gneiss; both similar in lithological character to the rocks farther to the north and east that have been fully described in former reports.

Though there is evidence of a considerable amount of folding—especially in the lower part of Glen Cannich, and near Deanie Lodge in Glen Strathfarrar—it is on the whole of a less complex character than that found in Strathconon.

The muscovite biotite gneiss is largely developed in the western part of the area, and forms broad and well defined belts that can be traced continuously for some distance, and give rise to the more rugged features of the mountains in the Broulin and Glen Cannich forests. The general strike of the schists in this region is—neglecting minor flexures—between N.N.E. and N.E., while the limbs of the isoclinal folds usually dip to the east.

On the north side of Glen Cannich, in the south-west corner of Sheet 83, the rocks form a part of a broad anticlinal fold, on either side of which the dip is to S.W. and S.E. respectively.

The siliceous schists and flagstones of the Moine series largely predominate in the district east of Strathglass, between Glen Urquhart and the Beauly River, and the original argillaceous sediments are only represented by thin bands of biotite-muscovite schist, characterised by large "spangles" of white mica. Some of the highly siliceous schists are crowded with small pale-coloured garnets.

The zone of amphibolite sills which crosses the river Farrar at Struy, has been followed southwards along the western side of Strathglass as far as the foot of Glen Cannich. They present the usual character of these intrusions. Two of these sills are cut, a short distance west of Glassburn, by a vein of coarse muscovite pegmatite. At the point of intersection both this vein and the basic sills, as well as the surrounding siliceous schist, are highly garnetiferous.

With the exception of a few thin dykes of lamprophyre and mica-trap there appear to be no igneous intrusions in the rocks to the west of this zone; though the usual knots and veins of pegmatite and quartzo-felspathic material, probably of segregative origin, are abundant, particularly in the coarser gneisses. One of these pegmatite veins on the shore of Loch Mullie, contains crystals

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Mr. Hinxman

of tourmaline. The later dykes, referred to above, have a persistent east and west trend, and though never more than a few feet in breadth, can be traced for considerable distances, in two instances for more than three miles. In a specimen taken from one of these dark Minette dykes above the farm of Mid Crochail, Strathglass, Dr. Flett has detected the presence of a sky-blue secondary amphibole deposited on the surfaces or in the cracks of brownish-green hornblende, and in optical continuity with the primary mineral. The occurrence of secondary blue amphibole in crystals of hornblende has previously been noted by Flett in a lamprophyre from the Orkney Islands, and by Seymour in a hornblende-kersantite from Co. Down, Ireland.*

A parallel system of north-east and south-west faults, one of which has probably defined the straight course of Strathglass, traverses the ground on the east side of that valley. The relations of one of the mica-trap dykes to these faults show that the latter are of different ages. The position of the dyke is shifted by two of these faults, but in a third case it has been intruded along the line of weakness produced by the dislocation, and bending sharply from its former easterly course, follows the north-east trend of the fault for a distance of half a mile. This portion of the dyke contains numerous included fragments of the fractured schists, none of which appear in it outside the fault.

*Ross-shire.*—The area mapped by Mr. Hinxman during the month of June in the Inverlael forest, is occupied by siliceous schists and flagstones of the regular "Moine schist" type, with occasional bands of dark biotite schist, often garnetiferous. The latter vary from a few inches to (rarely) thirty or forty yards in breadth, and in some cases give rise to well-marked cliff features on the mountain sides. These rocks are evidently the altered representatives of a homogeneous mass of arenaceous sediments, probably of the nature of an arkose, with a few thin bands or seams of argillaceous material.

A line drawn nearly due north through Meall nan Ceapraichean and Eididh nan Clach Geala, indicates the position of an axis of plication along which the beds are suddenly rucked up into sharp asymmetrical folds, one limb of the fold being nearly horizontal, while the other may be vertical or even slightly overfolded.

Another zone of extreme plication crosses the summit of Meall Dubh, three miles N.N.E. of Inverlael. The overfolding is here far more pronounced, and the limbs of the folds often appear to be lying horizontally and parallel to one another. The structure of the ground between these two lines is generally simple. The beds dip at uniformly gentle angles, in directions varying from east by north round to south by west. This appearance of regularity is however possibly deceptive, for even where the beds seem to be arranged in regular succession, the crests of flattened overfolds can sometimes be detected,

* H. J. Seymour. "Occurrence of a Blue Amphibole in Hornblende Kersantite." *Geol. Mag.*, Dec. 4, vol. vii., p. 257.

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and it is thus possible that only a small thickness of rock may be involved in the plications that cover a wide area. Mr. Hinxman

No igneous intrusions have been found in these rocks, but they contain frequent thin veins of quartz, and a few veins of pegmatite, both probably of segregative origin.

In the Allt na Lairige near its junction with the Douchary river, and also in the latter stream north of Creag Dubh, there are veins of quartz with which is associated a little plagioclase, felspar and a green pleochroic pyroxene which resembles ægirine augite. The pyroxene occurs in strings or amorphous masses in the quartz and also in isolated idiomorphic crystals.

*Physical and Economic features.*—The greater part of the area surveyed by Mr. Hinxman during the past season is wild mountainous ground, almost entirely given up to grouse and deer. The cultivated areas are confined to the alluvial stretches along the larger streams, and the grouse moors support a certain number of sheep during the summer, but the amount of good grazing ground is very limited.

Owing to the hard siliceous nature of most of the rocks and to subsequent glacial action, there is over the area occupied by the Highland schists little or no surface soil due to disintegration. The corries and higher parts of the glens are, however, often filled to a considerable depth with stony morainic drift, which is not as a rule favourable to vegetation.

The thin dykes of Minette which traverse the schists in Strathglass decompose readily into an orange-red soil, which, from the abundance of apatite in the rock, is peculiarly fertile, and gives rise to stripes of vivid green herbage that stand out in striking contrast to the surrounding barren schists. The lower ground in Kiltarlity and at the head of Glen Urquhart is more fertile, and much of it is under cultivation. The soil is here derived from drift deposits, usually loose and gravelly above, but passing downwards into stiff boulder clay.

Beyond a few small openings, for local purposes, in the flagstones of the Moine schists there are no quarries in the district surveyed.

Large areas on the hill slopes and in the higher valleys are occupied by peat mosses, often of considerable depth. The peat is dug to a small extent for fuel where it is fairly accessible, and may be of considerable economic importance in the future.

The population is sparse, very scattered, and confined to the valleys. Water supply is abundant, of excellent quality, and far in excess of the requirements. The potential water power represented by the numerous natural reservoirs, streams, and falls in the district, is very great, but has not, so far, been made use of.

The sides of the larger valleys are well clothed with natural woods of pine and birch, with oak on the lower slopes. In Glen Strathfarrar the pine grows well, up to an elevation of over 1,100 feet above sea level. Large areas in Kiltarlity have been planted with coniferous trees, and there are also smaller fir plantations at the foot of Glen Orrin and in the higher parts of Strathconon. The natural wood flourishes well on rocky slopes

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Mr. Hinxman

where the soil is scanty, and there is no doubt that large areas of the ground under 1,000 feet in elevation, that are now barren moorland, but are shown by the remains in the peat mosses to have been once thickly clothed with forest, might be profitably replanted.

Mr. Gunn.

*Ross-shire.*—The work done by Mr. Gunn in the Loch Broom area offers few points of interest apart from that of previous years, in the same district. For the most part the rocks belong to the siliceous Moine type of crystalline schists, the foliation of which dips at comparatively low angles of 10°–20° to points between south and south-east. The rock is generally flaggy and the dip is fairly regular over large areas. Folds or plications can seldom be detected, though good outcrops in scars and in burn sections are numerous.

On the south side of the Lael Valley, at its head, sharp folds trending somewhat east of north are extremely numerous, but as we pass westward down the valley, they disappear in the course of a mile or so, and we find a series of quartzose schists dipping regularly to the southwest at about 20°. The dip gradually changes so as to become due south about Glensguaib, and then east of south, which is the general direction along the valley of Loch Broom.

The structure of the ground for a long distance north of the Lael is similar to that south of this river, but as we approach Meall Dubh, where there are bands of biotite schist, we again find the rocks much plicated. To the northward of this hill, the beds again appear regular and the strike curves round, as along the Lael, being north-east at Leckmelm and south-east near Douchary.

The line of Coire Granda to the east of Beinn Deirg, nearly coincides with the axis of a large anticlinal fold which dies out to the northward in a series of rapid plications. To the east of this corrie for a long distance, the siliceous Moine-schist with occasional thin bands of biotite schist dip steadily in a north-easterly direction, which gradually changes to an easterly dip along the east side of Allt Lair, and the beds are comparatively free from visible folds.

Dr. Crampton

The ground on which Dr. Crampton was engaged during the month of June, is that part of the Inverlael Forest lying around the head of the Douchary River. It is difficult to reach, and the greater part of it is more than 2,000 feet above the sea. There is no population or cultivation of any kind on this ground, the whole area being very rugged and rocky, and under deer.

The crystalline schists are principally quartzose schists with varying proportions of micas. They are sometimes of a flaggy character, but mostly heavy gneisses, breaking up into large blocks. Alternating with the quartzose bands, are thin bands of a wavy bluish biotite schist, often containing garnet. They are largely developed on Meall a' Coire Glais and Tomain Coinich. Bands of garnetiferous mica schist, with larger proportions of muscovite, occur about the head of Chadha Dheirg, and on the eastern slope of the hollow leading thence to the head of

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the Glen Beag stream. Over the N.E. flank of Seana Bhraigh the rocks dip S.S.E. at angles of 15°–25°, and there is little folding to be seen. The rocks also dip at low angles, but due E. on Meall a' Coire Glais, while further to the south, round the Lochan Sgeirich, the dip is E.N.E. at angles of 20°–30°. Throughout these districts small escarpments and dip slopes are common features and the dips are constant over wide areas, but further east about the head of Chadha Deirg, and between this and Sron an Tomain Coinich, the folding begins to be marked, and contorted folding is beautifully shown in Creagan Tomain Coinich and the cliffs at the eastern end of Chadha Dheirg. Dr. Crampton

*Strathvaich.*—The part of the Strathvaich Forest, surveyed by Dr. Crampton from his station at Aultguish Inn lies between the Glascarnoch River and the Strathvaich River, and stretches northward along the west side of Strathvaich as far as Loch Toll à Mhuic.

The crystalline schists form nearly the whole of this area. They are chiefly granulitic quartzose rocks of the Moine type, with subsidiary bands of muscovite-biotite schist.

Along the western slopes of Strathvaich the strike of the rocks is almost due N. and S., but north of Aultguish Inn it becomes S. 10 E. —N. 10 W., and this is continued over Meall an Torcain, Tom Ban Mòr, and the heights further to the north. The folding of these schists is nearly vertical in the eastern part of the district, the dip being sometimes westerly sometimes easterly, but always at high angles. On passing westward the folds gradually dip at lower and lower angles to the eastward, till, near Airicheirie, the dip is E. 10 N. at 30°. In the intermediate areas, on the heights of Meall an Torcain and Tom Ban Mòr, the dips are 60°—45° gradually acquiring a lower angle towards the westward. Thin bands of brown biotite schist from a few inches to several feet in thickness are common all through the series, but they acquire a greater development on the line of strike, passing from Meall an Torcain over Meall Coire nan Laogh towards Carn Gorm Loch. Here a series of thicker bands some yards in width, but with intercalated bands of quartzose schists, occur, over a breadth of 300 yards. They consist of wavy bluish-black biotite schist, weathering a brownish colour. Small garnets are not uncommon. To the west of these biotite-schists bands, on the south-west slope of Meall an Torcain occur two well-marked bands containing many garnets. They cross Tom Ban Mor, and Meall Ghorm, to Meallan Ban, where they pass out of the district surveyed. The rock is a flaggy muscovite biotite schist, full of small perfect garnets, very similar to the muscovite biotite schists of Eastern Ross, but the structure is less coarse. Accompanying these bands are white pegmatites with large crystals of muscovite, and occasional garnet. A large pegmatite of this description with a breadth of 15 yards can be followed from near Craig Rainich, across Tom Ban Mòr, on to Tom Ban Beag, apparently following the strike of the schists.

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Dr. Crampton. About half a mile to the east of Aultguish Inn, a series of small crushes occurs in the schists exposed in the banks of the Glascarnoch River.

Mr. Gunn. Crystalline schists of the Moine type occupy most of the area on the east side of Strathvaich, to the north of Strathvaich Lodge. They have a prevailing northerly strike, generally trending a little to the west of north. The beds are usually vertical, or dip at steep angles to the westward, but sometimes the dip is easterly. Not much folding is visible in this area, nor are there any marked bands of biotite schist.

A pink-augen gneiss or foliated granite, which is intrusive in the crystalline schists, occupies all the area between Black Water and the Strathrannoch Burn, for a distance of 2½-miles northward from Inchbae Lodge. Much of this area is covered with drift and peat, and the rock is not well exposed, except to the north of the school-house at the Black Bridge, where it forms a fine series of escarpments trending a little west of north. The foliation in this place dips eastward at a high angle, but about Luibfearn in the direction of Inchbae, the dip is considerably to the south of east, and the amount is not generally more than 30° or 40°.

The character of this rock is the same as that described in the reports for previous years,* and therefore does not require a detailed notice. The rock extends for some distance to the east of Strathrannoch, and has again been encountered by Mr. Gunn in the Kincardine districts of Ross-shire, and by Dr. Crampton in Strath Rusdale and the neighbourhood—*See infra.*

Dr. Crampton. *Strathrusdale.*—In the Alness district of Ross-shire, Dr. Crampton who was stationed in Strathrusdale, found the greater part of his area composed of various kinds of crystalline schists with associated igneous rocks. The latter consist of the augen-gneiss and hornblendite sills. The north-eastern corner of the area is occupied by an intrusion of unfoliated granite. Two very small exposures of scyelite occur near the summit of Meall nam Gabhar.

The crystalline schists occupy the greater part of the area. The prevailing type of rock is a granulitic quartzose schist. A broad band of dark muscovite biotite gneiss is the only one which has been definitely traced across the whole area. This rock contains large flakes of white and black micas and strings of felspathic and pegmatitic material. It is frequently full of garnets, which are sometimes small with good crystalline faces, but often form aggregates from the size of a pea to that of a walnut and with a crushed appearance. This band is in places more than half a mile in width without any other kind of rock. It enters the area at the northern end of Ben Tharsuinn and crossing Strathrusdale in a S.S.W. direction extends as far as the Alness River in the Boath Valley where it is cut off by a fault. The band reappears on the S.W. shore of Loch Morie, about one mile from the outlet, and forms a crag facing the loch.

* *Summary of Progress* for 1898, p. 9, and for 1900, p. 8.

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It then passes over Meall Beag in a S.W. direction. The dips of this rock in the most northerly part of the band are very high and mostly in an easterly direction, but with occasional reversals to the W. As the band passes southward into Strathrusdale the dips have an E.S.E. direction at angles of 50°–60°. Further south and on the south side of the fault the dips become S.E. at angles usually about 45°. To the south and east of this band, and apparently overlying it, is a series of thin bands of a yellowish quartzite, weathering on the surface to a pure white, and alternating with bands of muscovite biotite gneiss of much the same character as the broad band described above. With these occur a thick series of flaggy granulitic quartzo-felspathic gneisses and bands of a more massive character, with a large proportion of pink felspar in strings and lenticles. Where the alternations of muscovite biotite gneiss and quartzo-felspathic rocks are more rapid there is a tendency for both members to become very flaggy in character, and to pass gradually from one kind of rock to the other through intermediate rocks called "spangle schists." These are granulitic quartzo-felspathic rocks of a very flaggy character and they contain scattered through them large flakes of muscovite which give the cleaved faces of the flags a spangled appearance. With these rocks are associated strings and lenticles of white pegmatite containing large crystals of white mica, which frequently enclose garnets. These pegmatites are sometimes of a large size and appear like dykes. The strike and direction of dip of all these schists which lie to the S.E. of the large band of muscovite-biotite-gneiss coincide in the main with the strike and dip of that band as described above. The broad belt of muscovite-biotite-gneiss on its N.W. margin is succeeded rather abruptly by granulitic quartzo-felspathic schists of the Moine type which appear to dip beneath it. Schists of this type devoid of bands of muscovite-biotite-gneiss, but enclosing some of biotite schists, occur all over the wide region to the west as far as Bad a Bhathaich and the northern end of Loch Morie. The strike and dip of these rocks follow the general direction of that of the schists to the eastward, but throughout the regions of Carn Beag and Craig Braigh ant Stratha and to the west of these elevations, the rocks are much contorted and folded, the dips being frequently to the S., S.W., and West. A thick band of bluish grey mica schist with a finely crimped structure caps Carn Beag and extends about one mile southward towards the outlet of Loch Morie. It is much interfolded at its margins with the underlying quartzose schists. Its general dip seems to be to the S.W., but there is much contortion. Along a line beginning at the junction of Allt Coire na Capuill with the Amhainn Glac ant Seilich and passing in a S.S.W. direction west of Bad a Bhathaich and thence through Meall Toll a Choin, above Kildermorie, the quartzo-felspathic schists give place to bluish-grey mica schists of the same type as those capping Carn Beag, but not so crimped and generally of a more phyllitic character. These mica schists dipping sometimes to S.E. and sometimes to

Dr. Crampton

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Dr. Crampton S. and S.W. pass gradually in a westerly direction into a bluish-grey hornfels. Rock of this type forms a zone of metamorphosed sediment, with a width of about half a mile, bounding the augen-gneiss described below. The minerals of the hornfels are usually too small to be distinguished with the naked eye. The rock as a whole has a very homogeneous appearance but distinct banding on a very small scale, evidently that of original bedding, is brought out on weathered surfaces. Near the margin of the augen-gneiss minute knots occur, and within a few yards of the junction large garnets have been developed and the rock is extremely hard and has a very baked appearance.

Dr. Flett has examined sections of the hornfels which has been produced by the augen-gneiss evidently acting as an igneous intrusion. He states that they are "finely banded hornfelses in which knots are well developed so that they may be described as Knotenschiefer. The banding is probably original bedding. Under the microscope they are fine-grained and consist of biotite, muscovite, quartz, and felspar. Small garnets spongy with enclosures are frequent. The knots consist of subradiate scales of pale mica. In one or two slides the original grains of clastic quartz are still to be traced in certain more gritty bands. Some of these hornfelses show no trace whatever of mechanical deformation subsequent to the thermal metamorphism." One of the specimens from Crag west of Kildermorie Lodge is a garnetiferous sillimanite biotite hornfels. Sillimanite in tufted needles is very abundant from the river bed west of Kildermorie Lodge. Another specimen shows garnets over ¼in. in diameter filled with enclosures of quartz, magnetite, etc. Clinochlore, green hornblende, and rutile are present. It is, therefore, evident that these rocks retained many of their clastic characters at the time of the introduction of the augen-gneiss, which in the respect of the hornfelsing has behaved as an igneous mass. In virtue of this hornfelsing they have escaped being converted into schists of the Moine type into which they pass out laterally.

The best exposures of the rocks of this metamorphosed zone are seen in the crags on both sides of the river above Kildermorie Lodge. There is also a good section in the river bed where the hornfels can be traced right up to its junction with the augen-gneiss. The junction is also exposed on the north bank of the river and at the summit of Carn Cas nan Gabhar.

Augen-gneiss, like that of Inchbae, is seen in junction with the hornfels in the river about half a mile above Kildermorie Lodge. The rock is a foliated granite in which a matrix of quartz, felspar, and black mica flows round large eyes of felspar. The line of junction passes in a N.N.E. direction up the Crag on the north bank of the stream, and the augen-gneiss has been followed to Carn Cas nan Gabhar, where it is seen near the summit of the mountain in junction with the schists. On the south bank of the river above Kildermorie Lodge the line of junction swerves to the N.W. and again crossing the river passes up the burn coming from Lochan Lice. The line

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of junction again changes its direction and is continued W.S.W. so as to cross the river once more about a quarter of a mile below the bridge. The strike of the foliation where observed is N.N.E. and S.S.W. The margin is rather abrupt in the region about Kildermorie, but small tongues and veins of the rock penetrate the schists. At the summit of Carn Cas nan Gabhar the junction can only be described as an intricate network of schist and igneous rock. Inclusions of schist are frequent within the margin of the gneiss, which sends out veins sometimes foliated like the gneiss itself but often quite devoid of any foliation, into the schists all along the boundary. The smaller veins are crowded with small rounded grains of blue quartz. Dr. Crampton

*Hornblendites.*—Small lenticular sills of hornblendite containing garnet occur associated with the muscovite biotite schists and also with the quartzose rocks. The largest, about 30 feet across, are seen in the Craig Ard a Briarh. The margins of these lenticles are well foliated and often show ball-like masses of crushed garnet wrapped in scales of brown biotite.

*Scyelite.*—Two small exposures of scyelite occur in the peat 300 yards N.N.E., and 400 yards E.N.E. of the cairn of Carn Cas nan Gabhar. They appear to have a somewhat dyke-like extrusion, but their relations to the surrounding rocks are not seen. Patches of a rock of a more acid character full of hornblende crystals are seen sticking to the scyelite in the more northerly exposure.

Dr. Flett, who has examined specimens taken from the more northerly exposure, calls the rock a biotite-hornblende-peridotite or scyelite. The beautiful lustre mottling seen in the hand specimen is due to the hornblende enveloping the biotite in poikilitic fashion. There is no shearing structure, but cracks and distortion of the biotite and hornblende, due to expansion of the olivines during weathering, are very noticeable. The rock closely resembles the original scyelite of Professor Judd (*Q.J.G.S.* 1885, Vol. 41). The more acid rock sticking to the scyelite is a quartz diorite of a basic kind almost approaching a hornblendite. Green hornblende, showing good crystalline outlines and brown biotite, are associated with a peculiarly acid interstitial material consisting largely of micropegmatite.

*Granite.*—A pale pink granite, an extension of a larger mass to the northward, occurs on the north-east flanks of Beinn Tharsuinn and Doire Leathann. Its constituents are a pink felspar, large clear quartzes with a strong tendency to good crystalline outlines, and small flakes of a brownish biotite. The latter is almost absent in some places, especially in the numerous veins which penetrate the schists along the margins. The metamorphism produced by the granite on the schists is very slight, and apparent chiefly in the direction of a greater development of muscovite. Boulders of this granite occur in conglomerate of Old Red Sandstone age about one mile distant in the Strathrory River. These boulders had been previously noticed by the late Hugh Miller. Dr. Flett reports on an examination of a slice of

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Dr. Crampton this granite, that it is a biotite granitite containing microcline. Orthite is present as an accessory.

The population in this area is distributed along the Blackwater River in Strathrusdale, and the district of Boath. It consists of the inhabitants of about a dozen crofts, who gain a living almost entirely by sheep farming. The only cultivated lands are narrow strips on the alluvia of the Blackwater and Alness rivers, and larger patches in the neighbourhood of Boath on the mudstones of the Old Red Sandstone. The crops grown are oats, turnips, and potatoes for home consumption. Kildermorie Lodge also lies in the area surveyed, and is surrounded by a few keepers' houses.

The boulders of augen-gneiss have been used largely throughout the district for the building of houses and bridges, One boulder supplied material for two cottages, with rock to spare. It is said that the rock splits well and makes an excellent building-stone. The method used for splitting the stone is called "pegging and feathering." Over the greater part of the district the land is not fit for cultivation.

Mr. Gunn. *Kincardine district.*—The principal rocks which are found in the Kincardine district are crystalline schists, augen-gneiss, and granite.

The crystalline schists of the Kincardine district are mainly of the siliceous Moine type. They are, in general, flaggy, with a fair amount of mica, especially on the bedding planes, but in not a few places they are thick bedded and very quartzose, and the mica is sparsely developed; while in some places the rock is massive, and the foliation obscure. The dip of the foliation is generally southward, and at high angles along the Carron River. The same dip is continued a good way up Allt Downie, but is less in amount, and the beds are repeated by a series of flattened folds. Over the large part of the Kincardine area the foliation dip is generally directed between E.S.E. and S.S.E., so that the average strike of the rocks may be said to be north-east. Near the northern edge of the main mass of granite, however, the strike tends to become parallel to the boundary line of the granite, or W.N.W. A marked example of this kind may be examined up Wester Fearn Burn. About Conà Chreag nan Clach there is a considerable area where the rocks are sharply plicated in a north and south direction.

Two broad bands of muscovite biotite-gneiss have been traced in the neighbourhood of Easter Fearn, and under Struie Hill. They are separated by a band of siliceous schist, which is half a mile wide opposite Struie, but which apparently becomes very narrow near Corriefearn, so that it seems probable one band is a folded repetition of the other. One of these forms Dun Criech, on the north side of the Dornoch Firth. There is no doubt that these bands are a continuation of one which has been traced by Dr. Crampton, in a north-easterly direction from Strathglass, across Strath Rusdale, till it is truncated by the granite north of Beinn Tharsuinn.

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Thin bands of hornblende-schist occur on the shore, and in the railway cutting two miles east of Easter Fearn, and some small masses of epidiorite and of hornblende rock are found in a few places. Mr. Gunn.

*Augen-Gneiss or Foliated Granite.*—The north-eastern extremity of the augen-gneiss or Inchbae rock, curves round from Carn Salach, and Carn Bhren, by Carn an Liath-bhaid to Meall na Cuachaige, but only a part of the boundary has been mapped. It is evidently of the nature of an intrusive granite sill which has been folded and foliated with the schists. In this district it appears to be everywhere in contact with rock which was once an argillaceous sediment, and which has undergone a great amount of alteration, having been converted in great measure into a hornfels with a development of contact minerals as andalusite, &c.

The width of this mass of igneous rock where it is known at either end (Inchbae or Carn Bhren), is from two to three miles, and it is probable that there is a continuous outcrop of it forming an isoclinal fold, stretching for about seventeen miles from its S.W. extremity near Beinn nan Cabag to Carn an Liath-bhaid at its N.E. boundary. This direction appears roughly to coincide with the general strike of the schists, into which it was intruded, and is in striking contrast with that of the greatest length of the mass of unfoliated granite which is found to the east of it, on the south side of the Dornoch Firth near Kincardine. The latter trends to the N.N.W., and cuts markedly across a thick band of muscovite biotite gneiss which strikes N.E.

*Granite.*—The mass of pink or red unfoliated granite stretches in a N.N.W. direction for a distance of six miles, from the Strathrory River beyond the Wester Fearn Burn, but the central portion of this area is not yet completed. Its average width is more than two miles. To the north of the main granite area small bosses and veins of granite occur in several places. They are particularly numerous along the shore south of Ardgay, and in Church Hill. This reddish biotite granite is in general moderately coarse, and the quartz which it contains often tends to become idiomorphic. The biotite is sometimes but sparingly developed. In places *e.g.* in the main part of Easter Fearn Burn, the granite is much decomposed, and very soft. There is a fine section of the rock in the gorge of the Wester Fearn Burn, where the granite is harder, and where it includes two broad bands of siliceous-schist.

As fragments of this granite are found in the lower Old Red conglomerate, it is clear that its intrusion was prior to the Old Red Sandstone period.

Two dykes of mica-trap running in an east-south-east direction pierce the schists in Allt na-h-Eiteig, and in Wester Fearn Burn dykes of a somewhat similar character penetrate the granite.

## OLD RED SANDSTONE.

*Ross-shire, Achilty.*—The mass of coarse basal breccia that forms the summit and eastern face of Torr Achilty lies between Mr. Hinxman

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Mr. Hinxman two faults, both with a down-throw to the east. These faults have been traced through the schists on the south side of the Conon, and after crossing that river they run in a N.N.E. direction, until they probably converge beneath the alluvial plain which lies between the base of Torr Achilty and the village of Contin. The most easterly of these faults throws down a pebbly conglomerate with intercalated beds of grey shale against the basal breccia on the west, which contains angular blocks of schist three and four feet in length. The breccia and the intercalated series on either side dip in opposite directions towards the fault. By the other fault the breccia is brought against the Highland schists half a mile further to the west. The down-throw of this fault on the southern face of the hill is evidently small, but on the north side the breccia lies in a deep hollow against a steep cliff of schist. Between the two faults the Old Red Sandstone rests unconformably upon nearly vertical beds of reddened and shattered siliceous schist.

*Inverness-shire.*—The western boundary of the Moray Firth Old Red Sandstone Basin has been traced southwards and eastwards from the Beauly river at Eskadale to the head of Glen Convinth. The base of the formation is everywhere a coarse conglomerate-breccia—a tumultuous aggregate of rounded and subangular fragments of all sizes, from small pebbles up to blocks three and four feet in length, set in a sandy matrix.

The included stones are almost entirely derived from the local crystalline schists, but there are also a few rounded boulders of unfoliated biotite granite and pegmatite, one of the latter measuring six feet in diameter.

A short distance in from the margin, beds of shaly greenish and red sandstone are intercalated with the conglomerate, but these do not exceed a few feet in thickness.

Mr. Gunn. *Strath Vaich Forest.*—The Old Red Sandstone occupies a strip of ground more than a mile in width, on the east side of Strath Vaich, between the Moine schists and the augen gneiss, and it runs a long way up the main stream of Strath Rannoch. An outlier of this formation also caps Meall-a-Ghrianain (2531 feet). The Old Red strata rest unconformably on both the older crystalline rocks, and its basal breccia is largely made up either of fragments of augen gneiss or of schist, according to the character of the rock on which it reposes. It appears that the surface of the crystalline rocks immediately prior to the deposition of the Old Red Sandstone must have been very irregular, and somewhat comparable to that of the Lewisian gneiss when the Torridonian formation was formed.

The Old Red Sandstone consists of breccias and conglomerates, sandstones, and mudstones. No regular succession can be made out satisfactorily as the ground is much obscured by drift and peat, and there are probably faults which are not visible. In the burns east of Creag Bhreac Mhor there are sections in purplish red mudstones, in which occur green streaks and also sandy bands. These latter show that the rock dips to the south-east at

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comparatively low angles of 15° to 20°, while the most prominent planes, those of cleavage, dip to the N.N.W. at angles of 50° to 60°. Mr. Gunn.

The outlier which forms Meall-a-Ghrianain is remarkable. As far as can be made out it consists almost entirely of blocks of augen-gneiss in a somewhat sandy matrix. The blocks are of large size, many being as much as ten feet in length, and there are some still larger. On the south-east side of the hill blocks of schist were also noticed in the conglomerate. There is no satisfactory outcrop on the hill top, which is covered with loose blocks of augen-gneiss apparently derived from disintegration of the breccia. The best section of the mass is on the west side of the hill about 550 yards W.N.W. of the ordnance station, and the cliffs there expose more than a hundred feet of the conglomerate. In one place there is an intercalated band of reddish sandstone one foot in thickness which has a gentle southerly dip, and this is probably the dip of the whole outlier, for the base of the mass must be 300 or 400 feet higher at the north than at the south end.

The large blocks of augen-gneiss so abundantly scattered over the area between Strathvaich and the Glascarnoch Valley were probably derived from this outlier, having been distributed during the glacial period.

It is difficult to account for the composition of this mass, as no augen-gneiss is known to occur *in situ* anywhere near it, and the blocks of which the basal portion is composed appear everywhere to repose on the ordinary siliceous Moine schists of the district. It is quite possible, however, that there is a core of augen gneiss *in situ* near the summit of the hill, concealed under the *débris* of the conglomerate.

The size of the blocks in this breccia is far above what usually occurs in the basal conglomerate of the Old Red Sandstone, in which the stones seldom exceed the length of two feet, and most of them are below that size. An exception to this, however, occurs in the basal breccia near its unconformable junction with the schist in the stream nearly a mile east of the summit of Meall-a-Ghrianain, where one of the blocks occurring in the breccia is 18 feet in length.

Reference was made to these areas of Old Red Sandstone in the Annual Report for the year 1896, p. 53, but they had not then been surveyed. It is known that rocks of this formation extend for a considerable distance to the east of Strath Rannoch but this part is not completed.

Three small outcrops of conglomerate which are found in the banks of the Strathvaich River between Lubriach and the Black Bridge were mapped by Dr. Crampton. Two of them are connected with the Old Red Conglomerate to the eastward, while the third which is the nearest to the Black Bridge is probably a smaller outlier. They consist entirely of schist pebbles in a red matrix. Dr. Crampton

*Alness District.*—A junction of the schists and Old Red Sandstone is to be seen in the Tollie burn one and a quarter mile above the bridge at Ardross gates. The Old Red Sandstone



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Dr. Crampton. distinctly faulted against the schists shows here a thin conglomerate which can hardly be separated from the brecciated schist occurring in the fault. The conglomerate is succeeded by red sandstones and thin purple and green mudstones all dipping to the S.W. The mudstones can be followed in the burn as far as Bractollie. The direction of the fault is N. 35 E.—S. 35 W.

The other area in which the Old Red Sandstone enters into the ground surveyed is in the Boath district. Here the line of junction of the Old Red Sandstone and the schists is partly a fault and partly also an unconformable one. The N.E. face of Cnoc Liath Fad down to the 1,000 feet line consists of a conglomerate of schist fragments and pebbles in a reddish matrix. On the south slope of the hill the conglomerate is in unconformable junction with the schists which at the W. end of the hill are in place as high as the 1,750 feet line. The line of junction has an abrupt descent at the N.W. end of the hill and crosses the low lying ground immediately south of Craig na Glaic and Boathvie towards the junction of the rivers near Strone. The basal conglomerate of Cnoc Liath Fad gives way to a series of purple and bluish-black mudstones in the low-lying ground about Glack, but the relation of the two sets of rocks to each other is obscure. There is however a thin basal conglomerate south of the Craig na Glaic. The whole of the low-lying area of Boath consists of purplish mudstones with occasional thin sandstone, which are well seen in the burn sections, but elsewhere they are largely covered by drift. These mudstones are limited in their northward extension by a fault lying a little to the S. of the Alness river, which brings them in contact with the schists. A second fault seen in the burn above Ballone brings the series against the schist to the south. Cnoc Liath nah-Acain forms the northern extremity of a ridge of conglomerate extending from Meall an Tuirc in Strathglass. The conglomerate is faulted against the schists to the W. by the great boundary fault the extension of which to the N.E. in the Boath district is obscured by drift. The dark bluish mudstones immediately to the W. of Glack show pale blue phosphatic marks which suggest fish remains, though nothing more definite has been observed.

### TERTIARY.

Mr. Clough. *Inverguseran.*—Tertiary Dykes are somewhat numerous in the south part of the Inverguseran district. Most of them are basaltic and tend N.W. or N.N.W.

### GLACIAL PHENOMENA.

*Glenelg District.*—Glacial striæ cross the Glenelg-Loch Duich watershed in Bealach Ratagain in the pass a mile N.W. of Sgurr Mhic Bharraich and in other places, one of them more than 2,500 feet high, further S. Granite boulders occur on the N.E. side of Bealachachasain house, and must have been carried over the watershed in a S.W. direction. Granite boulders have also

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been carried S.W. right across the main area of diorite and augite syenite on to the Lewisian gneiss rocks near Strathchomair. This probably indicates that the pressure of ice coming over the watershed from the N.E. and E. was at one time so great that the ice from the E. slopes of Ben Sgriol and Beinn a' Chapuill was unable to advance eastwards. Mr. Clough.

The floors and sides of the glens are to a large extent covered with small morainic mounds, but deposits of stiff grey boulder clay also occur. Excellent exposures of this clay are found near the heads of Ghleann Aoidhdailean and Bealach a' Chasain.

A little E. of Strathchomair, and on the low watershed between the Gleann Beag and Glen More of Glenelg, there is an extensive and thick deposit of fine sand and gravel. The materials composing the deposit are exposed in a good section, where they are quite free from large boulders, though such boulders occur in abundance scattered over the top and on the sides of the outcrop. The sand must have been deposited in still water, and probably in a loch, though it is difficult to see how a loch can have existed in this locality unless some of the banks were formed by ice.

A little N. of, and about 40 feet higher than, the sharp bend in the Gleann Beag burn are remains of an old gravel terrace, the top of which is nearly horizontal though the burn below has a rapid fall. The terrace is very near the deposit mentioned in the preceding paragraph and possibly of the same age.

On the E. side of the burn, about a mile S. of Bealachachasin house, is a series of seven or eight short terraces, the N. and S. parts of which end abruptly against moraine covered slopes of about the same elevation. Perhaps these terraces were formed while most of the glen bottom and the sides were still covered with ice.

*Funnich Forest.*—In the Fannich Forest, well-marked groups of moraines were found by Dr. Horne, in the valleys draining into the Cabuie river, and at the head of Allt a Chleibh, and Mr. Gunn reports that beautifully-formed moraines, which often trend nearly east and west are abundant to the east of Loch Li. Some of these, which are several hundred yards in length, are extremely narrow, run in almost perfectly straight lines, and have steep edges on their northern sides. Dr. Horne and Mr. Gunn.

*Inverness-shire and Ross-shire.*—The glacial drift in the higher parts of Strathglass and its tributary Glens, may all be referred to the later valley glaciation. It is only in the low ground valleys of Kiltarlity and on the northern slopes of Glen Urquhart that any true boulder-clay has been observed, in some cases underlying later morainic deposits. Mr. Hinxman

The glacial striæ and the dispersion of carried blocks in this region point to a general easterly movement of the ice outwards from the high mountainous region in the west.

Evidences of the later phases of the valley glaciation are abundant among the mountains of the Inverlael Forest, whose glens and corries afford splendid examples of lateral and terminal moraines.



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Mr. Gunn and Dr. Crampton

*Ross-shire.*—The finest set of moraines occurs on the north side of the River Lael, at An Cnapach (The Knolls) to the south of Lochan a' Cnapaich. The water of the loch disappears under the loose material of the more conspicuous moraines and comes out again to the south in several fine springs. A well-marked moraine 500 yards in length, which trends north-east, occurs on the water-shed north of the head of the River Lael, at a height of 2750 ft. above the sea, and there is a pretty series of moraines to the N.E. of this in the valley west of Loch Tuath. There is very little glacial drift in Dr. Crampton's part of the Inverlael Forest, and what occurs is of a loose character and full of blocks and fragments of the rocks in the immediate neighbourhood.

Mr. Gunn.

As will have been gathered from the description of Strathvaich Forest, much of the area is covered with glacial drift, but there are few good sections of it. The older boulder clay, or till, apparently overspreads a large part of the augen-gneiss area, assuming in Druim Buidhe the form of a drumlin trending south-east. Good examples of linear moraines are found in the valley east of Meall a Ghrianain, but perhaps the finest, which is nearly half-a-mile in length, occurs on the east side of a small stream to the north of Druim Buidhe. Large blocks of augen-gneiss from the conglomerate of Meall a Ghrianain, several as much as twelve feet long, have been distributed to the eastward, southward, and westward of the hill and they must have been carried, at one time, south-westward across the valley of Strath-vaich. This was probably when the ice had attained its maximum thickness, and the ice-shed was considerably to the east of the present main water-shed of the north of Scotland. It seems probable also that those found scattered on the Loch Broom side of the present water-shed (see *Report of Geol. Survey for* 1896, p. 18) may have also been derived from the same outlier.

Dr. Crampton

*Strathvaich.*—Dr. Crampton, in his area, finds that the drift is thickest in the lower part of Strathvaich, where it has been cut through by the river and terraced. It consists of a loose earthy accumulation of large and small boulders of schist and augen-gneiss. The western slopes of Strathvaich are covered with moraines full of similar boulders. A fine series of Kames occurs immediately south of Strathvaich Lodge. The most noticeable of these has a serpentine form, and is 600 yards in length. Augen-gneiss boulders are plentiful on the heights south of Tom Bàn Mòr. One on Sron Ghorm measures 18′ × 8′ × 5′. Ice striæ with S.E.–N.W. direction occur on the summits of Meall an Torcain and Sron Ghorm. Striæ near the base of Meall an Torcain have a direction E.S.E.–W.N.W. A few blocks of conglomerate are scattered over the summit of Meall Coire nan Laogh.

*Strathrusdale.*—Glacial deposits of great thickness occur in the valley to the east of Cnoc Liath nah-Acain leading from Boath to the junction of the rivers in Glen Glass. Sections of this deposit 30 feet in depth occur in the Allt na Seasgach, without rock being seen in the river bed. This drift has much the appearance of till, containing large, much-worn boulders of augen-gneiss and schist, and is full of smaller *débris* of schist and mudstone. It is quite

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loose and unconsolidated and appears to pass gradually into the thinner drift of the valleys to the westward. The low-lying ground to the east of Doire Leathann in the basin of the Strathrory river shows the same unconsolidated earthy drift of great thickness. Here, however, the predominant constituent is *débris* of the pink unfoliated granite which forms the ground to the N. and W. Small fragments of the Cambrian Pipe-rock occur in the drift of this area. One of the most noticeable features of the country is the quantity of immense boulders of augen-gneiss which occur everywhere up to the highest altitudes. Boulders of 10 feet diameter occur on the top of Beinn Tharsuinn. The largest boulder measured lies in the plantation to the N. of Bracantra in Strathrusdale. It is 61 feet in girth and 15 feet high. The augen-gneiss, however, occurs in places only three miles distant from this boulder. Fine examples of *roches moutonnées* are seen at the base of Cnoc a' Mhadaidh and on the opposite hill, Am Mam, and the striæ found upon them point E. 30 S., and their long axes are arranged in the same direction. A few boulders of Scyelite occur near the large augen-gneiss boulder. These have apparently been derived from the exposures of Scyelite on Carn Cas nan Gabhar, and lie in an E. 30 S. direction from the parent rock. Small morainic accumulations occur along the slopes in Strathrusdale. Dr. Crampton

*Kincardine District.*—In the Kincardine district there are extensive deposits of glacial drift, much of it of a morainic character and loose in texture. It appears to be thickest in the neighbourhood of the Easter Fearn Burn, east of Corriefearn. The main glaciation, as shown by striæ on the solid rock, was from the W.N.W., and conspicuous hills in the low ground, as Church Hill and Cnoc Bad-a-Bhacaidh, have long and thick tails of drift on their lee or E.S.E. sides. In the lower part of the Carron Valley and elsewhere are many mounds of sand and gravel or kaims. A pretty set of such mounds occurs to the south-west of Blar Garvary, near Abhuinn a' Choire Bhuig, at a height of nearly 900 feet above the sea. Well formed moraines are very conspicuous to the west of Gradal on the Kincardine Burn. Many large boulders of the augen-gneiss occur along the Kincardine shore, and they are particularly numerous down the Wester and Easter Fearn Burns. Mr. Gunn.

## POST GLACIAL.

Both the 25-feet and the 100-feet raised beaches are well developed near Inverguseran, and between that place and Airor. The 100-feet beach extends up Glean Ghuserein for two miles. Mr. Clough and Mr. Gunn

The Dornoch Frith is very shallow, and extensive modern deposits of mud are laid bare at low tides. Raised beaches are not conspicuous, except at the mouths of the principal streams. The 25-feet and 50-feet beaches can generally be traced on both sides of the Firth, but the 100-feet beach appears to be generally absent.

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## 2. West Highland District.—Knapdale, Lorne and northwards to Loch Eil, Skye.

Mr. B. N. Peach, F.R.S., District Geologist.

Mr. C. T. Clough,
Mr. J. S. G. Wilson,
Mr. H. Kynaston,
Mr. A. Harker,
Mr. C. B. Wedd,
Mr. H. B. Muff,
} Geologists.

Work was carried on during the season in two separate regions. The chief district is on the mainland in the counties of Inverness and Argyle, and stretches from Loch Shiel in the north to the Crinan Canal on the south. The one-inch maps in which this area is comprised are 36, 37, 44, 45, 53, 54, 62. The other district is in the Islands of Skye and Soay in Sheets 70 and 71.

The principal Geological Formations and rock groups dealt with are :—Highland Metamorphic rocks, and associated gneisses; Torridon Sandstone; Metamorphosed Cambrian Dolomites; Lower Old Red Sandstone and associated volcanic and intrusive igneous rocks; Triassic, Jurassic and Cretaceous strata; Tertiary volcanic and intrusive igneous rocks; Glacial deposits; Raised Beaches, Peat, and Alluvium.

### HIGHLAND METAMORPHIC ROCKS.

The region in which work was carried on in the Highland Metamorphic schists, under the supervision of Mr. B. N. Peach as District Geologist, stretches roughly along the west coast from Loch Shiel in the north to the Crinan Canal in the south. For convenience of description the region may be provisionally divided into two, viz. :—(*a*) one north of the Great Glen and the Linnhe Loch, and (*b*) one south of that line.

#### (*a*). *Region north of the Great Glen and the Linnhe Loch.*

Mr. Wilson.

Mr. Wilson is the only geologist who did field work in this district. The rocks in this region are chiefly schists of Moine type, and the muscovite-biotite gneiss. Though here described first in order it is not intended to imply that they are older than the schistose rocks south of the Great Glen. It has been shown in many former reports and *Summaries of Progress* that rocks of identical character with these occur over wide areas of country south of this line.

From his station at Corpach, Mr. Wilson continued fieldwork in Sheets 53 and 62, and mapped an area of 37 square miles, extending from a line drawn from the head of Loch Sheil south-west as far as the middle of Glen Scaddle, north-westwards to within a short distance of the upper end of Loch Shiel and the heads of Cona Glen and Glen Scaddle.

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Mr. Wilson.

The whole of this district is mountainous, and the different kinds of rock produce a poor and very inferior soil. The flagstones weather so slowly that any soil produced by their denudation is at once removed by the various atmospheric denuding agents.

The denudation of the muscovite-biotite gneiss to the west of the flagstones has produced very rugged and rough hill masses, which are either bare rock or else partially covered with a short, bright green herbage. This is due to the lodgement between the rock ledges and on the shelves of small and thin patches of light sandy soil derived from the disintegration of the gneiss. This soil is also scattered over the surface of the moraine slopes which cover the lower portions of these hills.

On both sides of Glen Scaddle the weathering of the foliated epidiorite has resulted in hills with long grassy slopes and rock ridges which culminate in sharp peaks. As this basic rock is much softer than the surrounding flagstones it has produced a considerable quantity of soil which is scatted over the lower hill slopes. This soil contains a small percentage of alkalies, etc., and as a natural result Glen Scaddle has the best grazing ground in this part of Argyleshire.

The larger portion of the grazing ground in North Ardgour is confined to the gravelly and sandy moraines, which are found in every valley and hillside. As the materials which compose these moraines are chiefly derived from the local rocks the grazing is only of a moderate quality.

Between the head of Loch Eil and Creggan there is a considerable belt of flat ground covered with deposits belonging to the 50-feet beach. When not covered by peat these haughs are fair grazing ground. The arable land is confined almost entirely to this raised beach on both sides of Loch Eil and the west side of Loch Linnhe. The crops grown by the crofters and on the farm lands include potatoes, oats, hay, with a few acres of turnips. With the exception of the hill pastures belonging to the various crofting townships the only grazing lands are confined to the lower portion of Glen Scaddle. All the remaining portion of North Ardgour has now been cleared of sheep and cattle and converted into deer forest.

To the south of the Creggag and Garvan, and in Glens Stronchreggan, Cona, and Scaddle, there are still to be found considerable remains of the old Caledonian Forest. Up to the beginning of the last century this part of Ardgour was covered with a forest growth, which was extensively cut down by the Bunawe Iron Co. and converted into charcoal, and shipped from Inverscaddle Bay to the iron furnace on Loch Etive. Large tracts of this country, which at present are barren moor, could be profitably planted up to a height of 1,000 feet.

There are no quarries or rock suitable for building purposes in this district.

The population is a scattered one, being confined chiefly to the crofting townships on Loch Eil and Loch Linnhe, and around Glen Finnan Railway Station. The stream water supply is good and abundant all over this district, but in no single instance has the abundant water power been utilised for industrial purposes.

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Mr. Wilson. The solid rocks which enter into the area are crystalline schists of Moine type, muscovite-biotite gneiss which form the "rocks of the country," and various igneous intrusions, some of which have been rendered schistose and metamorphosed, while others have retained their igneous structures, and are probably of later date than the metamorphism of the region.

The Moine schists or granulitic quartz schists with more or less felspar and mica form the south-eastern half of the area, and resemble the rocks described in former *Summaries of Progress* of which they are a continuation.*

The muscovite-biotite gneiss is a coarsely crystalline rock with muscovite and biotite in large flakes, and with quartz and felspar, which may be scattered either more or less regularly throughout, or may be arranged in layers, knots, and lenticles of varying size. The rock in places is flaggy and alternates with layers of granulitic quartz schist of Moine type, while in other places it becomes massive and coarse and assumes the appearance of a foliated igneous rock. In certain parts of the present area it is much traversed with knots, strings, and veins of quartzo-felspathic material, sometimes carrying muscovite or biotite, or even both micas, and the crystalline texture is often coarse, which in further descriptions will be named "pegmatites."

Rocks of the type of the muscovite-biotite gneiss, as above described, occupy nearly all the rest of the area surveyed; but this area is only the edge of a very wide belt of such rocks. A traverse was made along the line of the newly-constructed Mallaig railway while the rock cuttings were still fresh, and the muscovite-biotite gneiss belt was found to extend as far to the west as Kinlochailort station, the limit of the traverse, a distance of thirteen miles from the southern boundary of the belt. The direction of this section of railway is almost at right angles to the strike of the schists.

### *Igneous Rocks Associated with the Moine Schists and Muscovite-Biotite Gneiss.*

*Foliated Igneous Rocks.*—Between Glen Scaddle and Cona Glen Mr. Wilson mapped the extension of the Glen Scaddle intrusive igneous complex and two small outlying masses within the area of the Moine schists. The rocks consist of foliated epidiorite with its marginal zone of granulitic gneiss like that described in former *Summaries*.† He also met with diorite and grey basic dykes of the same type as those described in the *Summary* for 1900.‡

Amphibolites and hornblende schists occur as sills and dykes in the muscovite-biotite gneiss.

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* *Summary of Progress*, 1897, p. 65; *Ibid*, 1898, p. 40.

† *Summary of Progress* for 1898, pp. 40, 41; *Ibid*, 1890, pp. 45, 46.

‡ *Summary of Progress* for 1900, pp. 45, 46.

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*Later Igneous Dykes.*—Between Glen Scaddle and Loch Eil, Mr. Wilson. Mr. Wilson dealt with unfoliated granite dykes cutting and altering the Moine schist of the types mentioned in previous *Summaries.**

This year, dykes of a type of rock new to Scotland, which Dr. Flett describes as "Malchite," probably connected with the later granites of the region, were discovered in the railway cuttings near the head of Loch Eil. The relation of these to the schist and foliated igneous rocks as seen in the railway cuttings is described in the sequel.

Dr. Flett adds the following summary of their characters:— Dr. Flett. "Certain of the dykes in Glen Finnan are Malchites, *i.e.*, fine grained grey dioritic dyke rocks, consisting of hornblende (green, turbid) and biotite. They include rocks which correspond exactly to the typical Malchites of the Odenwald as well as others which differ from these in several important respects."

A few dolerite and basalt dykes of the ordinary type of Mr. Wilson. Tertiary age, and with a north-west trend, were met with throughout the area.

*Sections exposed in Railway Cuttings east of Glen Finnan Station.*—Between Glen Finnan station and Craigag (two miles) the newly-constructed Mallaig railway passes through a series of rock cuttings which afford excellent sections of the muscovite-biotite gneiss and its relations to the various igneous intrusions and pegmatites by which it is traversed. In these cuttings there is a considerable variation in the character of the gneiss. At the station the beds are very flaggy and micaceous, and contain a much larger percentage of muscovite than biotite, and are identical with the spangle-schist of the west of Ross-shire.† To the east of the station the beds become more flaggy and quartzose, being folded on a small scale on more or less vertical axes. Opposite the Roman Catholic chapel they contain several thin bands of zoisite-schist with wine-coloured garnets. In the cutting which forms the west approach to the viaduct across the Glen Finnan valley the rock is highly micaceous (chiefly biotite), and is intersected by numerous slip faults and small veins filled with quartz. Here the planes of foliation are often slickensided with chlorite, and the presence of chlorite appears to be entirely confined to the immediate vicinity of certain amphibolite masses and dykes which are associated with the schists at this point. On the eastern side of the viaduct the character of the gneiss changes, and for some distance it is a coarse massive banded grey and pink gneiss very similar to that of the eastern edge of the belt between Glen Scaddle and Cona Glen. On the west side of the county march and above the public road in Glen Callop, the rock is a coarse grey contorted muscovite-biotite gneiss chiefly composed of felspar with muscovite. Throughout the gneiss there are small detached strings and masses of pegmatite accompanied by thin

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* *Summary of Progress*, 1897, pp. 65, 66.

† *Summary of Progress*, 1897, p. 56.

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Mr. Wilson. irregular veins and masses of quartz. Iron pyrites is disseminated through the rock. On the east side of the county march several hard granulitic bands of quartzite are associated with the gneiss. Between the Craigag Lodge and the public road the muscovite-biotite gneiss is very similar in character to that portion on the west side of the viaduct, and has a large percentage of micaceous bands.

In the railway section already described the gneiss is intersected by a large number of dykes, sills, and masses of amphibolite, which never attain any great thickness. They are all foliated and appear to have been intruded into the muscovite-biotite gneiss prior to foliation. So entirely reconstructed are these igneous intrusions that it is now a matter of conjecture whether they were originally diorites, diabases, or gabbros. Many of these intrusions contain garnets which become larger and more numerous towards their edges, accompanied at the same time by a large increase of biotite. So characteristic is this increase of biotite that many of the smaller dykes are now entirely converted into a biotite-schist. The rock on both sides of the cutting at Craigag is intersected by several of these dykes, and one microscopically examined by Dr. Flett (9684), is described by him as a normal biotite-hornblende schist.

All these amphibolites are more or less cut by pegmatite veins, but it is a remarkable fact, that as these pegmatites approach an amphibolite mass or dyke, they sometimes disappear or else become very much attenuated where they traverse the amphibolite intrusions. Another interesting fact observed is, that when a muscovite-pegmatite vein comes close to or intersects one of these amphibolites, biotite becomes the chief mica in the pegmatite for a short distance on both sides of the amphibolites.

In a cutting on the east side of the county march several foliated amphibolite dykes send branches along the planes of foliation of the gneiss, which appear to coincide with the original bedding planes of the sediments from which the schist is derived.

In this section the muscovite biotite gneiss is intersected by numerous pegmatites which vary in size from less than 1 inch up to 10 and 15 feet in breadth. These intersect the gneiss and amphibolites, and in some cases a few of them traverse thin malchite dykes in every direction. The large pegmatites to the west have a general direction of N.E. and S.W. As a rule they are unfoliated, and appear to have been introduced after the foliation of the gneiss. An exception has been noticed in one of the large pegmatites in the second cutting on the east side of the viaduct, where the vein has a rude foliation continuous in direction with that of the gneiss. These pegmatites are largely composed of felspar with quartz and muscovite mica (sometimes replaced by biotite) scattered through the felspathic base. On the east of the viaduct the small streaks and lenticles are all more or less parallel to the foliation of the gneiss, and in many cases, are cut by the larger pegmatites that cross the foliation planes. This seems to indicate that the pegmatites are of

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different ages. The dyke-like pegmatites frequently cut one another, which shows that there were different periods of shattering and fissuring of the gneiss prior to their formation. The walls of these large pegmatites are clearly and sharply defined from the foliated gneiss, and the crystals of the different component minerals are often smaller next to the walls than in the rest of the vein. Mr. Wilson.

Malchite dykes traverse the muscovite biotite gneiss, amphibolite dykes and pegmatites. They are composed of a grey fine-grained holocrystalline rock, finest in grain next to the well-defined margins of the dykes. The breadth of these dykes varies from six inches up to six feet, and many of the smaller ones are slightly foliated. These are sometimes intersected by a few thin strings of pegmatite, which indicate that some of these "Malchites" were intruded towards the close of the period of the production of the pegmatites. In the second long cutting, to the east of the Glen Finnan Viaduct, there are five of the largest Malchite dykes between Glen Finnan Station and Craigag. In this section there are also several pegmatites measuring up to fifteen feet in breadth. These are cut at several points by Malchite dykes, but in no single instance was pegmatite observed to enter into them.

*Region South of the Great Glen and the Linnhe Loch.*

In addition to the tract already described, Mr. Wilson also surveyed a small area in Glen Nevis to the south of the Linnhe Loch. In continuation of his former work he traced the eastern boundary of the granite of Mullach Nan Coirean (*Summary of Progress* for 1899, p. 42), and the northern limit of the quartzite which forms the upper portions of Stob Ban and Sgor a Mhaim has also been mapped. This rock is a massive white quartzite with felspar. On the west side of Stob Ban, viewed from the east, it is seen to be folded twice on itself in a vertical distance of about 1,200 feet, the axial planes of the folds being nearly horizontal.

The biotite-schists (*Summary of Progress* for 1898, p. 47) which lie between the edge of the granite and the foot of the steep cone of Stob Ban are all contorted and folded more or less vertically. The quartzite dipping to S. and S.E. with an average angle of 35° seems to rest unconformably upon them. Several outliers of quartzite cap the north-west ridge of Stob Ban above Polldubh.

*Loch Awe District.*—With the view of finishing the survey of Sheet 45, Mr. Kynaston visited some of the islands near the head of Loch Awe, with the following result:— Mr. Kynaston

In completion of the Loch Awe area, Mr. Kynaston mapped the Island of Innischonian, near the head of Loch Awe, from Dalmally, and the small islands near Kilchurn Castle. The former consists of indurated black schists, with strong ribs of quartzite, and an occasional calcareous band. The schists are cut by a sill of hornblende porphyrite, and some small dykes of lamprophyre

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Mr. Kynaston. The smaller islands, near Kilchurn Castle, show the greenish phyllites and slaty beds of the Ardrishaig type, traversed by small sills of epidiorite.

*Inliers in the Lorne district.*—While mapping the Lower Old Red Volcanic plateau in the south-west corner of Sheet 45, several small inliers of crystalline-schists were observed by Mr. Kynaston and Mr. Peach. Of the areas surveyed by Mr. Kynaston, he reports:—

"In the area to the west and south-west of Loch Scamadale, inliers of the older rocks amongst the Lorne andesites, indicate the presence of pale grey and silvery phyllites of the Ardrishaig type. Again, two miles south-east of the head of Loch Scamadale, another inlier occurs, consisting of black slates with calcareous bands overlain by a coarse felspathic schistose grit or quartzite, of the 'Loch Awe' type, and intrusions of a coarse type of epidiorite, rich in felspar."

Mr. Peach. Extending north-eastward from Kilbride, about five miles south-east of Oban, there is an area, about a mile long and a few hundred yards in breadth, occupied by silvery grey phyllites, black-schists, and limestone, surrounded by the Lorne andesites. The limestone bands, which are thin, dark, crystalline and micaceous, are repeated by innumerable small isoclinal folds, the axial planes of which dip towards the S.S.E. The rocks are evidently the continuation of the limestone, the black-schist, and probably a small portion of the underlying phyllitic group met with in the Loch Awe region, the "Loch Awe group" of Mr. Hill.

Mr. Muff. *Lismore and adjacent Islands.*—In order to complete Sheet 45, Mr. Muff mapped the north end of the Island of Lismore, and some of the surrounding islands and skerries, and has supplied the following report on the crystalline-schists.

By far the largest part of the north end of Lismore is composed of a dark blue limestone, which is sometimes argillaceous. The limestone is finely crystalline, and contains scattered cubes of pyrites. The argillaceous portions exhibit some sericitic mica on the bedding planes, and often alternate in thin beds with purer limestone. The limestone is thrown into folds of no great amplitude, whose axes run N.E., S.W., and very nearly parallel to the south-east coast. The folds, though commonly vertical, may be inclined to the N.W. or to the S.E., and their axes may pitch to the N.E. or to the S.W. The limbs of the folds are commonly rippled by smaller folds. In spite of this folding and crumpling, the limestone must have a considerable thickness.

The black-schist, with vertical planes of schistosity on which sericitic mica is developed, crops out chiefly on the west side of the island. It extends along the shore beneath the limestone, and runs up into the cliff in folds. Its position on the coast is often marked by an indentation of the shore line from which a depression runs inland, but in more than one case, the limestone is seen to arch over the slates, showing that the latter rock underlies the limestone. The junction between the slates and limestone is clear and well marked.

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On Sliabh nam Ban-fionn, one mile W.S.W. of Port Ramsay, a breccia of considerable thickness rests on the limestone. It consists of angular and sub-angular limestone fragments, varying in size from small grains to blocks a foot or more across, lying in all positions in a limestone matrix. Some of these blocks are composed of contorted limestone, the folding of which appears to be anterior to the inclusion of the blocks in the breccia. A few pieces of black-schist occur here and there amongst the limestone fragments. On the shore, the breccia passes unconformably from the limestone on to the black-schist. The section is obscured somewhat by the intrusion of an igneous rock, referred to below, which has metamorphosed the rocks, and injected irregular veins into them in all directions. As to the age of the breccia, it is certainly of later date than the limestone and black-schist and it is cut by Tertiary basalt dykes and metamorphosed by the plutonic masses. The latter in some petrological characters resemble the igneous rocks of the Ben Cruachan complex, considered by Mr. Kynaston to be of Old Red Sandstone age. The breccia is provisionally placed amongst the schists. Mr. Muff.

Several small bosses of diorite, intruded into the schists, are surrounded by distinct aureoles of metamorphism. The black schist and limestone breccia are strongly hornfelsed. The purer limestone is altered to a whitish crystalline marble for several feet from the contact, whilst the argillaceous portions of the limestone have become a calc-silicate-hornfels. The chief soil on the surveyed portion of Lismore is derived from the boulder-clay, which forms a stiff clay soil with stones. Nearly all this ground, together with much that is covered by the gravels of the Raised Beach, forms arable land. Over areas not covered by boulder-clay, the folded limestone rises to the surface in long ridges and hummocks. It weathers along its exposed divisional planes, viz., bedding-planes and a perpendicular set of joints, forming more or less broken-down limestone-pavements comparable with the "clints" of the North of England Carboniferous Limestone. Along the lines of these widened bedding-planes and joints, there grows the bright green vegetation, which affords the pasture, for which the island is so well known, and which causes it to form such a striking contrast with the surrounding heather-clad mountains.

The limestone is now burnt for lime only at Port Ramsay, whence it is shipped to neighbouring coasts. Of the diorite masses, the one at the head of Allt a' Mhuilinn affords a better stone than the others, which are somewhat decomposed. The peat is not cut for fuel. The water supply is derived from springs which are abundant chiefly about the level of the 50-ft. beach. The gravel of the Raised Beach, owing to the springs, does not afford as dry a soil as might be expected.

The islands and skerries off the north and west coasts of Lismore, are composed of folded limestone and black-schist, traversed by dykes, which are similar to those of Lismore. Eilean Dubh, on the east, consists of white and yellow quartz-schist thrown into isoclinal folds, so that all the beds dip to the S.E.

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Mr. Muff. The rock is mostly fine-grained, a few coarser beds alone containing small crushed quartz pebbles. At the southern end, the strike swings round from a N.E., S.W. direction to one slightly W. of N., and thin-bedded quartzite, with thin partings of green phyllite, appear.

Mr. Kynaston *Glen Creran.*—Proceeding towards the south-east a small area of crystalline schists was mapped by Mr. Kynaston in Glen Creran, in order to complete the survey of Sheet 45 (one inch) for publication. Mr. Kynaston reports as follows:—

"On the east side of the glen the ground rises to 3,000 feet on the granite ridge of Ben Sguliàird, on the west side to about 2,200 feet in the area occupied by the black-schists and quartzites. The river Creran flows through fertile alluvial flats, bounded by steep wooded slopes. The hills are mostly grassy, with but little heather, and so afford good pasturage. The soil on the hill sides is in many parts calcareous, from the weathering of limestone and calcareous hornfels; in other parts there is much sandy material from the weathering of the granite. The population is confined to the glen, and is devoted to sheep-farming and agriculture.

"In continuation of last year's work, the area on the east side of Glen Creran was mapped up to the northern margin of Sheet 45, and the lines were carried on into Sheet 53 as far as Glenure. The schists of this area may be referred to the black-schists, grey phyllites with quartzose bands, and a banded calcareous series like that of the Pass of Brander, with occasional narrow zones of purer limestone. Intrusions of epidiorite are fairly common, but they are usually small and frequently behave rather as dykes than sills.

"The influence of the Ben Cruachan granite, which occupies all the higher ground on the east side of the glen, is distinctly noticeable in the schists, at a distance of nearly two miles from the granite margin. As we approach the granite, the schists become intensely hornfelsed, and constitute the continuation of the hornfels zone, which has been traced to this area from the head of Loch Awe and the Pass of Brander."

Messrs. Peach, Wilson, and Muff. *Kilmartin District.*—In continuation of work done in former years by Messrs. Symes and Hill in the west of Argyleshire, Messrs. Peach, Wilson and Muff, during the autumn, mapped a small area of crystalline schists. The area, which is about two or three miles broad, extends from the western end of Loch Avich in the north, to the Crinan Loch on the south, being bounded on the west by the Barbreck River and Loch Craignish. It includes most of the islands in that loch. The northern part of the area was mapped by Mr. Peach. A small intermediate area lying along the boundary of Sheets 36 and 37 was surveyed by Mr. Muff. With the exception of one square mile at Slockavullin, south of Kilmartin, the rest of the area was mapped by Mr. Wilson.

The Kilmartin area is a portion of the low table-land into which this part of the west of Argyll is carved, irrespective of the nature of the rocks which enter into it.

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Towards the S.S.W. the table-land is about 400 feet in general level, rising gradually towards the N.N.E. to over 1,000 feet, the highest point being attained in Carn Duchara, which is over 1,700 feet in height. This part of the table-land is carved into a series of parallel rocky ridges with a N.N.E. and S.S.W. trend, corresponding to the outcrops of sheets of epidiorite constantly repeated by folding, which resist the weather more effectually than the sedimentary rocks into which they were intruded as sills. The two principal streams which drain the area are the Barbreck River, running into the head of Loch Craignish, and the Kilmartin Burn, a tributary of the Add. Both of these run along the strike in wide valleys, the lower parts of which are hollowed down to below sea level and which are continued seawards as sea lochs. Terraces of alluvium and various raised beaches are found in the lower part of both valleys. The high alluvial terraces of the Kilmartin Burn being partly due to water which drained out of Loch Awe at a period when the upper end of the loch was obstructed by glacier ice and the temporary outlet of the loch was at the S.W. or Ford end. The side streams are necessarily short and steep, and often run along lines of fault or along the courses of basalt dykes, which traverse the area in a N.W. and S.E. direction in great numbers. It is along these lines also that the few narrow passes that cross the area are found. Messrs. Peach, Wilson, and Muff.

The table-land is for the most part occupied by rock, but there are a few patches of Boulder Clay and morainic drift, the moraines being only found near the head of the Barbreck River, and on the plateau south of Loch Avich. As a rule the hollows on the table-land correspond with the outcrops of schist of sedimentary origin and are floored with peat or swamps, and an occasional small loch. In the higher regions a thick swathing of peat covers almost the whole surface except the rocky hill tops and escarpments.

The decomposition of the epidiorite gives rise to a scanty soil which, where not covered by peat, supports a grassy vegetation while the peat and quartzite give rise to heath and bents. The higher part of the table-land is, therefore, entirely given over to sheep and grouse moor, while a few Highland cattle are reared. The steeper slopes are often covered with grassy vegetation, especially where, in addition to the *débris* of the epidiorite, the underlying rock is limestone. These slopes are infested with innumerable rabbits, which are trapped and sent to the market in great numbers.

Cultivation is now almost entirely confined to the alluvial terraces and the raised beaches, and is mainly directed to the wintering of the live stock. It has been much more extensive at no distant period and carried well up the slopes, especially where limestone and decomposing epidiorite form the subsoil. Even yet these old cultivated spots form the best grazing grounds in the whole district. In this, as well as in nearly every district in the West Highlands, these patches of old cultivation are overrun with the common bracken *Pteris aquilina*, which is spreading to an enormous extent and spoiling wide tracts of good pasture.

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Messrs. Peach, Wilson, and Muff.

The population is chiefly confined to the lower parts of the valleys, and is thicker than in most parts of the West Highlands, the mixed grazing and cultivation which the region affords having formed an attraction ever since the first of the Gaels colonised the region early in the present era.

The schistose rocks entering into the area consist of phyllites, limestones, and quartzites, of sedimentary origin, with sheets and dykes of epidiorite and chloritic schists, some of which have undoubtedly been intrusive igneous rocks, and others may probably have been lava flows.

As the area on its eastern border is contiguous with that mapped by Mr. Hill in former years, and as his lines have been continued into the present area, there can be no doubt that the rocks represent Mr. Hill's "Loch Awe Series," and part of the "Ardrishaig Phyllites." It was found desirable to sub-divide the rocks of sedimentary origin further than was carried out by Mr. Hill. The natural grouping of these rocks and their order of succession appears to be as follows:—

(e) Quartzite. Fine grained above and passing down into a coarse pebbly grit below, the pebbles consisting chiefly of quartz, many of them of bluish tinge, and a considerable number of felspar. One small pebble of graphic granite was found by Mr. Muff. The matrix of the grit in places becomes highly calcareous and the rock in places passes down into the following

(d) Pebbly Limestone. A dark limestone more or less sandy throughout, with pebbles of quartz and felspar identical with those found in (e), and with fragments of black limestone, phyllite, black-schist, a few well-rounded pebbles of fine-grained quartzite an inch or two in diameter. In places the limestone becomes a breccia of dark limestone and black-schist fragments.

(c) Limestone. Dark fine-grained crystalline limestone in thin layers intercalated with dark calcareous slates or phyllites.

(b) Black slates and phyllites interleaved with light-coloured siliceous bands and grey phyllites, and passing down by gradual intercalations of grey phyllites into

(a) Grey and green silky phyllites, some of which are sandy.

The rocks of sedimentary origin occupy scarcely half the area, the rest being occupied by epidiorites and later igneous intrusions. Both the schists and epidiorites are thrown into a succession of sharp folds, the long axes of which run approximately N.N.E. and S.S.W. Both limbs of most of the folds dip towards the S.S.E., but there are a few exceptions to this rule where the folds are normal. As well as this minor folding the rocks are arranged on a larger scale in a compound anticline along the eastern border of the area, while the rest of the area forms part of a compound syncline. The result of this structure is that the grey and green phyllites (a) are mostly to be found along the ridge forming the watershed between Loch Awe and Glen Domhain and Loch Avich. Passing westwards from this line these rocks alternate with the dark phyllites (b) and limestones (c), while the pebbly limestones (d) and the quartzites (e) are the chief rocks met with in the centre and west of the area. While this is the general disposition of the rocks,

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however, the lower rocks frequently show themselves even in the central and western part of the area on the crests of the sharper minor anticlines, so that the whole series cannot be a thick one, even with the addition of the epidiorite sills. Messrs. Peach, Wilson, and Muff.

During the mapping of the area a considerable amount of evidence was obtained to show that the quartzite (e) and the pebbly limestone (d) are unconformable to the limestone (c), the black slates (b), and the grey phyllites (a). The nature of the evidence is twofold. First, the pebbly limestone (d) often contains fragments of the dark limestone (c) and dark phyllites (b), where the two rocks are adjacent to each other, and the bottom beds of the pebbly limestone (d) sometimes consist of a breccia of these two rocks. Grey silky phyllite fragments, like those of group (a), also occur both in the limestone and the quartzite. There can be no doubt, therefore, of the derivative nature of the bed, while in numerous sections the pebbly limestone (d) is seen to shade up through calcareous grits into the quartzite (e). Second, the quartzite, which usually overlies the pebbly limestone, in places overlaps it and rests on the black slates (b) and limestones (c), and even on the grey phyllites (a). The calcareous grit or pebbly limestone also transgresses the edges of the underlying rocks in places. The evidence, therefore, is very much in favour of an unconformability between the quartzite and pebbly limestone on the one side, and the limestones and phyllites on the other.

Epidiorites, occurring chiefly as wide spread sills folded with the sedimentary schists, occupy more than half the area. Two different types can be made out on the ground:—

1. A fine-grained rock, slaggy and highly vesicular at its margin, sometimes showing an arrangement of phacoids with vesicular outer layer and a non-vesicular interior suggestive of the "pillow structure," visible in certain lava flows. Sills of this rock are usually associated with the phyllites and limestones and apparently produce little or no metamorphic action upon the neighbouring sedimentary rocks. In part of the area they are continuous with rocks already reported on by Mr. Symes (*Summary of Progress* 1899, pp. 61, 62) and Mr. Kynaston. Their likeness to certain basic lavas has been noted by Mr. Teall (ibid. *Summary of Progress*, 1900, pp. 33, 42, 44, and footnote p. 34).

2. A more massive rock, coarse in texture, and with few or no vesicles. These sills are usually associated with the limestones and quartzites, and produce a certain amount of contact metamorphism, converting the impure limestones into calc-silicate hornfels. A sill which extends over a considerable area in Glen Domhain, where it is intruded into the quartzites, is so full of large porphyritic felspars that it looks as if it had been an andesitic rock prior to its alteration. All the epidiorites are in places more or less foliated, and chlorite, epidote, and zoisite are the most common minerals. All are more or less calcareous, and in the slaggy portions the amygdules of calcite make up half the bulk of the rock. The microscopic characters of the above type of rocks have been already given in Mr. Kynaston's report for 1900. *Summary of Progress* for 1900, pp. 32–35. Mr. Hill has also described the characters of these rocks as developed in ground adjacent to the present area. *Summary of Progress*, 1900, pp. 41, 42.

Crush, or pseudo-conglomerates were observed by Messrs. Peach, Wilson, and Muff in ground mapped by them respectively. They occur generally where the pebbly limestone is associated



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Messrs. Peach, Wilson, and Muff.

with sills of epidiorite. From the fact that what appear to have been continuous bands of shale are now represented by rows of isolated phacoids or **S**-shaped masses of slate in a pebbly limestone matrix, we are inclined to accept Mr. Hill's explanation for part, at least, of the phenomenon. Mr. Muff, who has mapped the best examples, gives the following description of what occurs in his area.

Mr. Muff.

"The structure described by Mr. J. B. Hill, under the name of 'crush conglomerates,' has been met with in several localities in the pebbly limestones usually near the junction of that rock with epidiorite. More or less lenticular blocks of epidiorite, whose long axes are approximately parallel, lie inclined at high angles to the line of junction. The best exposure occurs at a cliff 1,200 yards north by east of Salachary. Two undulating bands of phacoidal masses of epidiorite, commonly between six inches and one foot in length, and with highly inclined long axes, cross the face of the pebbly limestone. A third, but shorter, belt is composed of phacoids of black slate embedded in the limestone." Mr. Muff is also of opinion that some of the vesicular phacoids found in the fine-grained epidiorite may have had a similar origin. He reports on them as follows:—"An Samhladh, and the ground to the north-east is composed of folded schistose epidiorite, which contains bands of uncrushed vesicles filled with calcite. In many places, lenticular masses, up to two feet in length, consisting of an outer coat of vesicular epidiorite, and an inner core of more schistose epidiorite, lie with vertical long axes, in schistose epidiorite, the planes of schistosity of which conform more or less to the edge of the lenticular masses. It is possible that these lenticular masses have been formed by the nipping off of the crests of the folds composed of an outer coat of highly vesicular and an inner core of strongly schistose epidiorite."

## TORRIDONIAN.

Mr. Clough.

*Island of Soay.*—In order to complete the Survey of Sheet 70 (one inch), Mr. Clough undertook the mapping of the Torridonian rocks of the Island of Soay, and has supplied the following report:—

"The Island of Soay, though nearly all composed of bare rock and peat, is conveniently situated for the herring and the lobster fishing. The population is consequently not so sparse as in many parts of the Highlands, and it diminishes in summer, as many of the younger men are then away, engaged on yachts and tourist steamers.

"The island is essentially composed of Torridonian rocks, and of Tertiary intrusions. The Torridonian rocks dip somewhat steadily W. at about 15°, and are not altered nor veined with quartz, and there is nothing to suggest folding or thrusting. They are divisible into three groups, which are as follows, beginning at the top:—

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"1. Leac Faoileann group. Pale pink, rather fine-grained false-bedded grits. Thickness about 270 feet. Top not seen. Mr. Clough.

"2. Beinn Bhreac group. Red and purplish red false-bedded grits, with pebbles from half an inch to two inches long, of quartzite, felsite, andesite, and jasper. Thickness about 2,200 feet.

"3. Leac-Stearnan group. Pale pink false-bedded grits, with thin bands of grey sandy shale. Thickness about 900 feet. Base not seen.

"The rocks in group 2 closely resemble those in the Applecross group of the mainland."

A large N.W. fault cuts the island in two, with a downthrow on the N.E. side about 700 feet. This fault does not appear to affect the plateau basalts on the north side of the Sound of Soay, and it is probably of pre-Tertiary age. Another fault, tending N.N.W., passes a little east of Beinn Bhreac, and has a downthrow to E.N.E. of about 90 feet. The fault seems of earlier date than a thin sill of porphyritic basalt. Various other faults can also be proved to have taken place prior to certain igneous intrusions.

*Isle of Skye.*—Mr. Wedd, while mapping the Secondary rocks in the Sconser, Loch Sligachan, and in the Strathaird Districts of Skye for the completion of Sheet 71, met with some small inliers of Torridonian rocks. Owing to their isolation there is no direct evidence as to the exact subdivision of the formation they belong to, but there is no doubt as to their Torridonian age. Of these inliers Mr. Wedd reports as follows:— Mr. Wedd.

"Near Sconser, this sandstone, hard and compact, sometimes coarse and pebbly, either pink and felspathic or light grey, lies in an anticlinal fold on and below the northern slope of Glamaig. It is brought up again further west by N.W. faults at Glac Fhearna. In Strathaird, Torridon rocks occur at Camasunerie. They consist in part of hard, fine, and coarse-grained, compact sandstone, often pebbly, and changing irregularly from light grey to pink, with many grains and pebbles of felspar, and of very hard finely laminated shales. At Camasunerie the shales occur only as thin layers in the sandstone, but west of Camasunerie they form thick beds underlying massive sandstone. The relation of these thick shales to the rest of the Torridon sandstone of Camasunerie is obscure."

## CAMBRIAN.

*Metamorphosed Cambrian dolomites of Strath in Skye.*—A re-examination of the metamorphosed equivalents of the Durness Limestone group in Skye became desirable in the light of Mr. Teall's work on the similar rocks at Ledbeg in Sutherland and Dr. Pollard's chemical investigations published in the *Summary of Progress* for 1900. The metamorphism is exceptionally well displayed in the vicinity of the Tertiary granite and gabbro of the Broadford district. Accordingly Mr. Harker revisited these localities in conjunction with Mr. Tait, who collected a typical series of specimens. Mr. Harker.

The results go to show that the rocks must have been in great part dolomitized, and often completely, prior to the igneous intrusions, and have been more or less completely dedolomitized



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Mr. Harker. by metamorphism in the manner described by Mr. Teall (*l.c.* pp 153, 154). The dolomite has been reduced to calcite, the magnesia giving rise to other minerals. A common type among the resulting marbles is a rock consisting of calcite and forsterite, the latter often in perfect crystals, which show prominently on a weathered face. From this type come also at least the majority of the serpentinous marbles or "ophicalcites" of the district, the serpentine being derived from forsterite, which is often seen partially destroyed. Other minerals found in varieties of the marbles are diopside, tremolite, white mica, idocrase, and a violet spinel. Such rocks must have been originally impure, chiefly owing to disseminated chert, but pure dolomites have also been dedolomitized. The result in this case is a pure white rock consisting simply of calcite and brucite, and comparable with the "pencatite" of Predazzo in the Tirol. It seems probable that periclase was first formed, and has been converted to brucite by hydration; but neither periclase crystals nor unmistakable pseudomorphs after them have been detected.

## LOWER OLD RED SANDSTONE.

Messrs. Peach and Kynaston. *District of Lorne.*—In order to complete Sheet 45 (one inch) with a view to its publication, the remaining unsurveyed portion of the Lorne Volcanic Plateau, which enters into that sheet, was mapped by Messrs. Peach and Kynaston during the season.

In the autumn and early winter, Mr. Peach, in intervals between other duties, mapped a small area round Loch Nell and the head of Loch Feochan.

Mr. Peach. *Feochan Area.*—The area surveyed by Mr. B. N. Peach during the year is part of the Lorne Volcanic Plateau which here rises to a general level of over 500 feet, the greatest height being over 900 feet. The plateau is trenched almost to sea-level by the two branches of the Feochan River which runs into the head of the sea loch of the same name. The floors of the valleys in which the rivers run are flat and their sides steep showing a step-like series of escarpments corresponding to the outcrops of the successive lava flows. The side streams join the main valleys through deep straight-cut ravines, which coincide either with lines of fault or with igneous dykes, the shattered rocks and decomposing dykes being more readily removed by the streams than the more solid andesitic lavas which they traverse.

The surface of the plateau is for the most part very irregular and almost bare of drift but, in some of the hollows and flats, there is a sparse coating of morainic material which is usually covered with peat and gives rise to a heathy vegetation. Above the general level there rise irregular rocky tops with the characteristic stair-like escarpments. Towards the western portion of the ground, the surface of both the flats and the rocky hillocks is dotted with moraines. Some well-defined trains of boulders are strewn across the ground and can be traced up to their parent rocks, which always lie to the westward of the trains, while the

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sources of others, such as those of the Cruachan granite blocks, lie outside the present area. The varied conditions of the plateau give rise to a mixed vegetation favourable for sheep grazing and for summer grazing for the hardier varieties of young cattle and horses. On the sides of the valley and between the escarpments where the slopes are not too steep, the disintegrated igneous rocks produce a thin soil which gives rise to a scanty but sweet vegetation, affording summer grazing for cattle and sheep; while the cultivation is almost entirely restricted to the alluvial lands and the raised beaches which floor the valleys, but the ground is at present cropped mainly to support the live stock. Dairy farming is carried on by some of the farmers as there is a great demand for milk during the tourist and yachting season at Oban, which is within easy reach. The population which is entirely occupied in farming, is sparse and confined to the valleys. Mr. Peach.

The climate is mild and wet, and as there are several lochs along the course of the streams there is a constant supply of good water both summer and winter. Copious springs issue on the sides and bottoms of the valleys, chiefly from the fault-breccias and lines of dykes which traverse the andesites in large numbers

Trees, both conifers and hardwoods, grow luxuriantly where sheltered from the sea winds, even upon the steep *débris* covered hill-sides, and sometimes on the rocky escarpments themselves.

The andesitic lavas supply material for drystone dykes and rubble for masonry, and the harder varieties afford good road metal, but the best road metal is obtained from the dolerite and basalt dykes which traverse the area in great profusion. The numerous boulders of Cruachan granite which are strewn over some parts of the area afford excellent material for corner stones, lintels, and such work where massive stones are required.

The raised beaches and alluvial deposits afford a good supply of gravel and sand for concrete and mortar.

Peat occurs in considerable amount both on the plateau and on the 100-feet raised beach, but is not at present much worked as coal is found to be more economical.

The prevailing rocks in this area are andesitic lavas, some coarse conglomerates, and fine tuff and basement conglomerates, and red and grey shales.

These rocks are arranged as follows: The basement conglomerates, overlain by red and grey shales like those of Oban, here rise on a low dome from beneath the andesites at the south end of Loch Nell and are visible on both sides of the loch. In the high plateau lying between Loch Nell and the foot of Glen Lonan, and the Feochan Bheag, the grey shales are succeeded by andesitic lavas which dip gently to the south and east from off the dome, being only separated from each other, in most cases, by their own slaggy upper and under surfaces, and forming a succession of craggy escarpments. One thin zone of agglomerate, tuff, and red shale, lying at a level of 300—400 feet from the base, has been traced from Torr an Tuirc near the head of Loch Nell, by Barnacarry and Kilmore to near Kilbride. Above this zone shattery

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Mr. Peach. fine-grained andesite flows form successive escarpments for a few hundred feet, and are then succeeded by massive coarse porphyritic hypersthene-andesites which cap the highest ground and cross the area from Kilmore to Glen Lonan. Lava flows of this type are succeeded to the east of the present area by a zone of mica-andesites of more acid character, which were mapped by Mr. Kynaston and are described by him.

In the small area south of the head of Loch Feochan mapped by Mr. Peach, successive flows of basic andesite dip gently towards the north-west.

Both of the above areas are traversed by dykes of hornblende-porphyrite, quartz-felsite, and lamprophyre, of the same general age as the lava-flows. This appears to be the northern edge of a zone where the dykes are increasing in number southwards from the present area. Both the lavas and these dykes are cut by numerous basic and acid dykes with a north-west and south-east trend which are probably of Tertiary age.

Mr. Kynaston *District between Taynuilt and Loch Scamadale.*—This area consists almost entirely of hilly ground, rising to a height of nearly 1,700 feet above sea-level, and is occupied by the Lorne volcanic series. It constitutes essentially a denuded lava-plateau, intersected by small, though often steep-sided glens. The slopes of the hills are often terraced by well-marked lines of crag and escarpment indicating the outcrop of successive flows, while the higher ground frequently forms an uneven heather-covered table-land, throughout which numerous knolls and crags of rock stand out among peaty and marshy hollows.

The lavas, especially the more basic types, are usually much decomposed and disintegrated, and break off readily into small angular fragments. The rock takes on a yellowish or brownish crust, and is purple, or sometimes brick red on fracture, in contrast to the almost black colour of the fresher varieties.

The soil is thin and poor, almost the entire area being given up to grouse moors, and sheep pasturage. The only portions under cultivation are the alluvial flats in the glens, and the raised beaches and river terraces, where the soil is good and fertile.

The rock is often quarried for road metal, and for stone walls, and occasionally for building purposes.

The population is restricted to the glens and the low ground near sea-level.

In the Taynuilt area the general dip of the volcanic series is south-east, and it is often possible to map out individual flows and trace them for some distance. To the west of Taynuilt a considerable area is occupied by a dark purple andesite, with porphyritic crystals of plagioclase and greenish pseudomorphs after hypersthene. This rock is well seen in a roadside quarry, 1½ miles north-west of Taynuilt, also in Airds Park, whence it may be followed across the wooded ground to the south-west to the conspicuous hill of Deadh Choimhead, on the north side of Glen Lonan. Apparently beneath this flow we find in Airds Park a much more acid type of rock, similar to the felsitic lavas

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of Glen Nant, described in the *Annual Summary* for 1897, p. 84. As in Glen Nant we have here also a finely banded structure due to flow, and the occasional occurrence of a coarsely spherulitic or nodular variety, with numerous nodular bodies up to about half-an-inch in diameter. The same rock is again well seen south-west of Taynuilt, to the west and north-west of Balindore, and forms the wooded knoll west of Barguilean. Flow brecciation is occasionally seen, and there is, as in Glen Nant, a frequent association with hornblende and mica andesites. To the south of Taynuilt and on the west side of Glen Nant, the felsitic lava is again well exposed at and near Taylor's Leap, together with hornblende- and mica-andesites. Mr. Kynaston

Beneath the felsitic lava there is a dark grey compact andesite, which appears to cover a considerable area immediately to the south-west of the Taynuilt raised beach. This is a more basic type of lava than the hypersthene andesite, noticed above, only rarely showing porphyritic felspars and containing numerous specks of the reddish-brown mineral ( ? iddingsite) which occurs mostly as pseudomorphs after olivine. Beneath this basic flow we find conglomerates with some red shales and gritty beds, seen in numerous exposures south-west of Taynuilt. The conglomerate shows a high proportion of quartzite boulders, andesite boulders being also common, though more local.

Interbedded with the basic andesite of Airds Park, N.N.W. of Taynuilt, we have a band of an acid tuff. It is compact and flinty in texture and varies in colour from reddish-purple to a pale yellowish. It is often crowded with small fragments of felsite, with some of andesite, and shows biotite flakes and crystals of an acid felspar. A precisely similar tuff is again seen in the higher ground further south, cropping out below the upper crags of Cruach Ard-dhuine, where it is intercalated between narrow bands of red shale and sandstone.

The lavas, both above and below the bands of sediment, are of a basic facies, and may be referred to either felspathic types of olivine-basalt or a very basic andesite. The lower flow rests upon conglomerate, and is highly vesicular towards its upper portion.

Farther to the south-west, and in the area south of the upper part of Glen Lonan, the normal lava is a somewhat basic andesite, which, in the higher part of the area, is capped by a well-marked flow of mica-andesite. This latter constitutes the upper part of Carn Gaibhre, and stands out conspicuously in the crags of Creag-an-Fhithich to the south. It is again well seen on the south side of Beinn Ghlas, and covers a considerable area to the north-west of Lochan Dubha. The rock is often felsitic and shows flow-banding. Flow-brecciation is also very common, numerous angular felsitic fragments being embedded in a reddish matrix. The rocks which overlie the mica-andesite are well seen in a crag section half-a-mile north of Lochan Dubha. Resting upon it we have a flow of basic andesite, allied to basalt, above which is a well-marked band of andesitic agglomerate and ashy material, overlying which is a purple porphyritic (?) hypersthene-andesite.

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Mr. Kynaston The agglomerate appears again on the west side of Lochan Dubha and is well exposed in the conspicuous Creag Mhor, south-east of Kilbride in Glen Feochan, and has been followed for some distance above the mica-andesites on the south side of Glen Lonan. Its fragments consist entirely of different varieties of andesite in a finely fragmental matrix. They are occasionally more or less rounded and often attain a diameter of 4 or 5 feet.

The basic lava below the agglomerate is often highly vesicular, the vesicles being represented by amygdules, often as large as hens' eggs, of reddish agate with an inner layer of crystalline quartz.

South of Kilbride, in Glen Feochan, the high ground (Creag Ghlasrach, Righ Roc, etc.) consists of a dark purple porphyritic andesite, with numerous phenocrysts of plagioclase and a green mineral, probably a pseudomorph after hypersthene. The rock is often very vesicular, but the non-vesicular portions often closely resemble the intrusive porphyrites, owing to the comparatively large size of the phenocrysts and the reddish colour of the weathered surface. This type of flow covers a considerable area south of Kilbride, and is continued to the north side of Loch Scamadale.

Further east, in the region about the Sior Lochs and Beinn Dearg, east and south-east of Musdale, considerable masses of tuff have been mapped and were seen to be bedded between rather basic types of andesite. This is a rather less acid tuff than that of Airds Point and Cruach Arddhuine, and is similar to the rock mapped by Mr. Symes near Achnacloich, and by myself near Taynuilt and already described.*

Mr. Peach. The volcanic rocks in this area must rest on a very irregular floor of older rocks, for an elongated inlier of black shales and limestones (see *ante*, p. 124) rises from beneath the porphyritic lavas near Kilbride, which must be separated from the basement rocks visible on Loch Nell by a thickness of more than 1,000 feet of basic lava flows, the edges of which must abut against this old floor of schistose rocks.

Mr. Kynaston Inliers of the older rocks are seen in several places in the area about Loch Scamadale, one to the south-east of the head of the loch, above Fineglen, occurring at an altitude of over 1,100 feet, and forming the bed and slopes of a portion of the glen. These inliers afford interesting evidence of the kind of surface over which the lavas were poured out.

An important result of the mapping has been the recognition of the wide distribution of more acid types of lava-flow, such as hornblende-and mica-andesites and felsites, and various pyroclastic rocks. This may serve to connect the Lorne series with that of the Blackmount and Glencoe, where the more acid types are a characteristic feature. We may note, too, the not infrequent observation of basic having succeeded more acid material.

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* "On some Tuffs associated with the Andesitic Lavas of Lorne." *Trans. Edin. Geol. Soc.*, vol. viii., p. 87.

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In the *Summary of Progress* last year, p. 71, Mr. Kynaston described the induration noticeable in the andesites and conglomerates as they are followed towards the Pass of Brander. This year he obtained further evidence of a similar kind at the north-west end of the Pass. Thus, in the railway cutting close to the Awe Viaduct, intercalated in the andesites, is a band of laminated shales and grits, the induration of which is very marked. The granite is not more than three-quarters of a mile from these beds, a distance at which it may well have indurated the sediments without appreciably affecting the andesites. At the entrance to the Pass of Brander the andesites are well exposed on the south-west side, and appear to be decidedly indurated, and show small veins and bands, a few inches in breadth, of a rock allied to porphyrite, but approaching microgranite in texture. Above the cliffs on this side there is a band of conglomerate and grit, which again shows decided induration. Mr. Kynaston

*Dykes and Sills.*—Dykes and sills, belonging to the same volcanic period as the lava-flows, are exceedingly numerous throughout the greater part of the area mapped, and maintain, as a rule, the usual N.N.E. and S.S.W. trend. The mapping has shown that the area most thickly intersected by these intrusions constitutes a kind of belt or zone, about a mile in breadth, stretching from the area immediately south of Taynuilt to the high ground south of Loch Scamadale. The intrusions are mainly hornblende- and biotite-porphyrites, similar to those described in former reports. Occasionally more basic types are found, often closely resembling the normal andesitic lavas, while more acid varieties have affinities to quartz-porphyry. Intrusions of quartz-porphyry, cutting the andesites, have been mapped in several places in the area S.W. of Taynuilt, and closely resemble those occasionally associated with the Ben Cruachan granite.

Dykes allied to lamprophyre have also been observed, though they are not common. North-east of Loch Scamadale a dyke occurs closely resembling a mica-diorite. Another dyke, of unusual type in this district, occurs in Glen Nant, a quarter of a mile south of Tailor's Leap. The rock is allied to the hyperites, and may be termed a hypersthene-diorite-porphyrite. It shows under the microscope [9652], large phenocrysts of zoned plagioclase, idiomorphic hypersthene altered to bastite, and pale greenish augite, in a granular ground-mass of plagioclase with some alkali-felspar and a little quartz. Such dykes form connecting links between the andesitic lavas, and the hyperite modifications of the granites.

*Kingshouse area* (*Blackmount and Royal Forests*).—This area is a wild mountainous tract, the highest point of which rises to slightly over 3,600 feet, and is occupied by the Blackmount and Glencoe volcanic series and granite. On the east, the wide stretches of peat, and moraines of the Moor of Rannoch, are in striking contrast to the conspicuous heights about the head of Glen Etive and Glencoe. Mr. Kynaston

Among the volcanic rocks, the hornblende-andesite weathers with a pale grey or whitish crust, and forms conspicuous crags,

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Mr. Kynaston often much broken up by joints, so producing much scree material. The breccia and agglomerate is more massive, and weathers into comparatively more rounded masses with a rough surface, and breaking away in large angular blocks. The felsite forms striking precipitous crags, with well-marked vertical joints, and disintegrates into sharp angular flinty fragments. The granite forms rounded hill-tops, often flanked by steep crags with characteristic jointing.

To the east lies the western portion of the Moor of Rannoch—a table-land with a granite floor, weathering to a fine quartzose sand, covered by moraines and peat-mosses, while in the hollows lie numerous lochs and lochans, showing varying degrees of silting up. The peat, where of good quality, is used for fuel, also the numerous stumps of Scotch fir which occur in it so abundantly.

There is no cultivation, the ground being entirely deer forest.

*Volcanic Rocks.*—The mapping of the volcanic area to the north of the Clach Leathad was continued by Mr. Kynaston during June from Kingshouse. The principal types of rock which constitute the volcanic series have already been described in the *Summary of Progress* for last year, so it will be sufficient here to give a summary of the more recent progress of the work as regards the behaviour and relationships of the rock-masses, with a brief account of certain fresh facts of interest. The mapping of the rhyolitic felsites, breccias, and hornblende-andesites of the long north and south ridge, on the north side of the Clach Leathad, was completed. The andesites occupy the highest ground and form a roughly oval area, invaded on its south and west sides by the Blackmount granite. The rocks are mostly typical hornblende-andesites, though augite-bearing varieties also sometimes occur. On the north and east sides of Stob Glas Choire a zone of 20 to 30 feet of dark grey laminated shales and grits was found intercalated in the andesites. The beds are much indurated by the granite. Below the andesites we find the breccias, apparently underlying them in a normally bedded manner. In its upper portion the breccia is often of finer material, and occasionally shows gritty bands, and well-marked signs of bedding. The breccias sweep round the northern margin of the andesites, capping the ridge at Sron Creise, and thence bend round to the south-west and are cut off by the granite. While examining the breccias in detail in two or three places, Mr Kynaston found fragments of a rather acid biotite-granite, resembling that of the Clach Leathad. That they were derived from the granite of the Blackmount is, however, not possible, since this latter is clearly itself intrusive in the breccias.

The rhyolitic felsites are seen apparently underlying the breccias on the north-east spurs of Stob Glas Choire and below the summit of Sron Creise. They rise up in precipitous crags on either side of the Càm Ghleann, and thence stretch north westwards, below Sron Creise, to the river Etive, being terminated abruptly to the south-west by the intrusion of the granite. From the river Etive the felsites were traced further north-west and

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were found to be continuous with the felsitic masses of the Buachaille Etive Mor. Along its north-east margin the felsite shows a sharply defined junction with the older schists. The contact face of the igneous rock is usually vertical or almost so, and behaves apparently as an intrusive rock, and often shows a narrow border of breccia. Outside the margin, small oval-shaped and dyke-like intrusions of the felsite are common in the schists, and in the Càm Ghleann occur two small plug-like intrusions of augite-andesite. Mr. Kynaston

Passing to the Buachaille Etive Mor, on the north-west side of Glen Etive and west of Kingshouse, we find evidences of bedding well indicated. Thus at the foot of the north-east crags of Stob Dearg the base of the series is formed by a bed of conglomerate (15 feet), resting upon the schists, and overlain by reddish and purple shales. Above the shales lie bedded conglomerate and breccia, which are overlain by the rhyolitic felsites. Practically the whole of the east face of Stob Dearg consists of different varieties of felsites. The rocks show a most perfect flow structure, and flow-brecciation is common. About half-way up the east face a band of dark purplish and greenish shales is seen in the felsites, and coincides with part of an obliquely descending line of feature called the "Crowberry Traverse." These beds are again well seen in the bed of the gulley immediately south-east of this feature. On the north side of Stob Dearg the breccias are well bedded and contain gritty bands.

The intercalations of sediment above described closely resemble, both lithologically and in mode of occurrence, the sedimentary bands so common among the lavas of Lorne, and constitute strong evidence that the volcanic series of the Blackmount and Royal Forests is of the same age as that of Lorne. The shales of the "Crowberry Traverse" closely resemble the indurated sediments seen in the railway cutting near the Pass of Brander.

As already stated, the granite of the Blackmount is seen cutting each member of the volcanic series along the western slopes of the Sron Creise ridge. The contacts are remarkably clear, and the evidence of the alteration of the volcanic rocks has been established beyond any room for doubt, both in the field and with the microscope. Veins of granite and pegmatite are sometimes seen traversing both the andesites and the breccias, and the granite veins occasionally contain fragments of the breccia. It is obvious, therefore, that the fragments of granite in the breccia must evidently have been derived from an older granite mass, or may indicate an earlier plutonic phase belonging to the same period of igneous activity. A parallel case may be found in the occurrence of fragments of granite and gabbro, in the agglomerates of the Cuillin Hills of Skye.*

* See Harker, "The Sequence of the Tertiary Rocks of Skye," *Geol. Mag.*, Dec. 4, vol. viii., p. 507.

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Mr Kynaston

*Dykes.*—The final period of eruptive activity was marked by the formation of numerous dykes, with the normal N.N.E. and S.S.W. trend. These are mostly of hornblende and mica-porphyrite, but quartz-porphyry and andesite are not uncommon. The resemblance between these dykes and the similar types of intrusion which cut the Lorne andesites and the Ben Cruachan granite, is so close, and their behaviour and intimate association with acid and intermediate lavas and plutonic masses so similar, that one can hardly doubt that they belong to the same period of vulcanicity. Intrusions of lamprophyres, or allied rocks, are comparatively rare, only one case having been noticed this season, namely of a rather basic rock allied to camptonite, cutting the schist on the north slopes of Sron Creise.

*Glen Creran, Ben Cruachan Granite.*—The mapping of the western margin of this granite was continued by Mr. Kynaston from Glen Creran, and the boundary line was traced from Coire Buidhe, east of the head of Loch Creran, along the western slopes of Ben Sguliaird to the upper part of Glenure. The larger portion of the rock is a biotite granite, relatively poor in hornblende, while a more acid pink granite is frequently exposed on the higher ridges of Ben Sguliaird. Inclusions of hornfels are common.

In the upper part of Glenure, N.N.E. of Ben Sguliaird, is a mass of augite-diorite, of a type formerly observed in Glen Strae. It extends from the south bank of the river Ure up to the granite margin on the slopes of Ben Sguliaird. It does not pass into the granite, but appears to be interbanded with it in a rather complicated manner. The same rock is again seen along the granite margin on the north side of An Grianan, and doubtless represents a more basic modification of the same magma from which the granite was derived.

Associated dykes in the Glen Creran area, as yet mapped, are confined to a few small lamprophyres.

Mr. Muff.

*Lismore Granite Masses.*—During the mapping of the metamorphic rocks in the north of the Island of Lismore, in Sheet 45 (one inch), Mr. Muff met with several small bosses of plutonic rock in which were represented several rock types similar to or identical with those found round the margin of the "Cruachan" massif. These are associated with a similar set of dykes like those surrounding the Cruachan area. Both sets of rocks are in turn cut by one or more types of Tertiary basic dyke. A strong presumption is, therefore, raised that these rocks belong to the same general period of intrusion as the Cruachan granite.

Mr. Muff supplies the following description of these bosses and dykes in Lismore:—

"Four plutonic bosses of small size appear within the area. The first forms a small promontory on the west side of the island a quarter of a mile north of Sliabh nam Ban-fionn. Its form, as shown in the cliffs, is that of a blunt cone with concave slopes. A second boss rises as a dome-shaped hill immediately N.E. of

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Sliabh nam Banfionn. A third occupies the circular hollow at the head of Allt a' Mhuiliun, and is surrounded by high walls of altered limestone. It is crossed by a Tertiary basalt dyke. Two small outcrops on the side of the large peat moss at Sron-na-Craoibhe probably belong to a fourth boss. Mr. Muff.

The rock composing those bosses appears to be typically a medium grained augite-diorite, usually with abundant biotite. Hornblende often surrounds the pyroxene and a very little quartz is present. A specimen from the head of Allt a Mhuilinn containing rather more quartz and abundant orthoclase, shows a passage to the tonalites. The boss near Sron-na-braoibhe and that a quarter of a mile N. of Sliabh nam Ban-fionn exhibit basic marginal varieties. A specimen from the latter (10,106) described by Dr. Flett as "an augite-biotite-diorite-porphyrite, shows large idiomorphic phenocrysts of pale green pyroxene, abundant porphyritic biotite less perfectly formed, remains of serpentine after olivine, and a ground-mass of hypidiomorphic plagioclase and orthoclase. In some respects it resembles a kentallenite." Several small veins of aplite which contain an unusual amount of plagioclase cut this basic margin of the boss, but basic varieties are not always present along the margins. Near the contact of the boss mentioned second above with the limestone breccia, a fine-grained augite-porphyrite is seen. The latter has injected abundant irregular veins into the former, whilst the igneous rock is crowded with fragments of limestone and limestone-breccia. All these bosses are accompanied by aureoles of metamorphism which are narrow in the purer limestone, but broaden out in the argillaceous limestone and black schist. The purer limestone is converted into a whitish marble for several feet from the contact, whilst the impure limestone forms a calc-silicate-hornfels.

Amongst the numerous dykes, it appears possible to recognise (1) a set of N.E. lamprophyre dykes, (2) irregular mica lamprophyre dykes, (3) a set of dykes varying in composition from basalts to andesites which traverse the island from W.N.W. to E.S.E. and are probably of Tertiary age. The north-easterly lamprophyre dykes appear to be vosgesites. They are very irregular, sometimes appearing as branching dykes, sometimes as a string of lenticular masses, end to end. A certain small amount of movement appears to have taken place subsequent to their intrusion. On the low promontory immediately west of Port Ramsay, and elsewhere, the W.N.W. basaltic dykes cut them. It has not been shown that these lamprophyre dykes cut the plutonic masses, but apparently they enter the aureole of metamorphism without undergoing alteration.

The mica-lamprophyre dykes include the largest dykes in the area, the best examples appearing on Eilean Ramsay and the neighbouring skerries. It cannot be said that they follow any particular direction. They are younger than the plutonic masses, for not only is an unaltered dyke seen to penetrate the metamorphosed limestone, but small lamprophyre veins cut the diorite.

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Mr. Peach. *Glen Domhain Granite.*—While mapping the crystalline schists in Glen Domhain, near the edge of Sheets 36 and 37 (one inch), Mr. Peach traced for over a mile the southern and eastern boundary of the granite mass mentioned by Mr. Symes in the *Summary of Progress* for 1900, p. 49. The mass is fine grained near its edge, and often of a rather basic type, resembling the hyperites that are found near the margins of the Galloway granite masses. The alteration in the schists and epidiorites is intense close up to the granite, but dies out within a comparatively short distance, and is similar to that described in former summaries.*

## TRIASSIC.

Mr. Wedd. *Isle of Skye.*—In order to complete the mapping of the Secondary formations in that part of the Island of Skye which enters into Sheet 71, Mr. Wedd resumed the work of last year, as reported in *Summary of Progress*, 1890, p. 113. His work was carried on in four separate districts—(1) Sconser, on Loch Sligachan; (2) Strollamus and south of Scalpay; (3) Strathaird and Torran; and (4) the district of Strath between Lochs Slapin and Eishort.

Rocks of Triassic age were met with in two of these localities, viz., Sconser and Strathaird. About Sconser they consist of conglomerate, made up of pebbles of Durness (Cambrian) limestone and chert and Torridon sandstone, red sandstone, and red and light green marly beds, the conglomerate predominating near the base. At the top there is often a bed of hard fine-grained light green sandstone. In this area these rocks are often much metamorphosed. At a point 300 yards E. of the second milestone from Sligachan in a burn section some thin, soft, light marly sandstone lying between two igneous sills, overlying a hard, coarse, blue-streaked grit, and underlying the lowest Lias limestone, may probably represent the thin beds provisionally assigned to the Rhætic in Strath.†

In the district of Strathaird (3) a thin quartz conglomerate occurs at the S. end of Blath Bheinn. On the west side of its southern spur, a thin blue limestone conglomerate is visible beneath the base of the highly metamorphosed Lias. These conglomeratic beds probably both belong to the same group as the beds assigned to the Trias which occur elsewhere in Skye.

## JURASSIC.

### LOWER LIAS.

*Isle of Skye.*—The Lower Lias in the Sconser district consists of thick micaceous shales and beds of calcareous micaceous sandstone, both with Arietite Ammonites and *Gryphæa arcuata:* Below these is a thin series of blue limestones, with shale near the top, two coral beds near top and bottom, bands of *Gryphæa*

* *Summary of Progress* for 1899, p. 63; *Ibid*, for 1898, p. 86.
† *Summary of Progress* for 1900, p. 113.

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near the top, and a bed of small oysters near the base. The lime- Mr. Wedd.
stones are perhaps not much more than 30 feet in thickness. No separate division of calc-sandstone at the base can be recognised as in the Broadford beds, neither can the sandstone which immediately overlies the limestones be found. The *Bucklandi* and *Semi-costatus* beds are recognisable. In district (3), N. of Torran, highly metamorphosed blue limestones with beds of shales in the upper part, and possibly a coral bed, dip steeply towards the S. and S.W. from off the granophyre on either side of the Strath Beag. They are succeeded by thick micaceous shales with sandy beds, considerably metamorphosed. The shales contain obscure ammonites and pectens, not yet determined, and in the upper part, beds of *Gryphæa*. It is clear that here is the lower part of the Lias, but it is difficult to say how far up in the series the strata extend. In Strathaird, N. of Camasunerie, Lower Lias occupies the upper part of the valley of Abhuinn near Leac, and forms the lower slopes on the E. and W. sides of the south spur of Blath Bheinn. It is intensely metamorphosed by the plutonic rocks, and also by innumerable dykes. It consists of thick shales and sandstones overlying thin blue limestones intercalated with shales and containing bands of *Gryphæa* with thicker limestone below. The whole is highly metamorphosed, but the few traces of ammonites obtained, together with the beds of *Gryphæa*, are enough to show the Lower Liassic age of the series. A little patch of the same limestone was seen near the mouth of Abhuinn Camas Fhionnairidh. In the Strath district (4) Lower Lias has been mapped, as usual a thick series of micaceous shales and micaceous sandstones with *Gryphæa*, &c., above thin blue limestones with thin shales, along the east shore of Loch Slapin and the north shore of Loch Eishort. The *Bucklandi* and *Semi-costatus* beds are recognisable.

### UPPER LIAS.

*Isle of Skye.*—A small exposure of Upper Lias was noted by Mr. Tait at one point on the east coast of Strathaird beneath the shingle of the beach, while he was collecting from the lowest beds of the Inferior Oolite. It contains abundant Ammonites of the *Communis* and *Serpentinus* groups.

### INFERIOR OOLITE.

*Isle of Skye.*—In the Sconser district (1) a massive strip of white sandstone is seen at intervals on the north shore of Loch Sligachan. Below Torr Mor it passes up into shaly sandstone and sandy micaceous shale with a bed of impure graphite above. As no fossils were procured Mr. Wedd is unable to say to what part of the Oolitic series the beds belong, as they are completely isolated and no great thickness is seen. In the district of Strollamus (2) very thick metamorphosed white sandstones, laminated in the lower part, form the coast and eastern slopes of Glas Bheinn Bheag. Calcareous doggers occur and seem to contain obscure belemnites. In the upper part are one or two beds of shale and of

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Mr. Wedd. highly calcareous sandstone or sandy limestone altered to sandy marble. A comparison of the whole sequence at Strollamus together with evidence from the sandstone itself and from the fossils of the overlying series, clearly shows that these metamorphosed sandstones are the Inferior Oolite of Strathaird. The intrusion of the granophyre mass of Beinn na Cro and Glas Bheinn Bheag reverses the dip in anticlinal form between the two localities. In Strathaird a thick series of sandstones, more or less calcareous, white at the surface but blue when fresh, and often passing in the lower parts into beds of gritty blue limestone, forms the whole of the eastern side of the peninsula. Beds of *Avicula*, *Pecten*, *Terebratula* and *Rhynchonella* occur at several horizons. As these beds overlie the Upper Lias and pass up into the Great Estuarine series, they clearly comprise the Inferior Oolite, but whether they include any higher horizon or not depends upon whether the lower part of the Great Estuarine series is strictly homotaxial or not with the Great Oolite. A bed of black pyritous shale of variable thickness separates some 30 or 40 feet of white sandstone at the top from the sandstones below. The shale is marine and contains locally, badly preserved impressions of ammonites, but no clearly determinable specimen has been obtained. The Inferior Oolite sandstones can be recognised in a highly metamorphosed state on the east flank of Sgurr nan Each near the head of Loch Slapin.

### GREAT OOLITE (*Loch Staffin Series*).

*Isle of Skye.*—At Strollamus (2) the thick sandstones are succeeded by a series of shales and sandy limestones; both are often crowded with small bivalves (*Cyrena ?*). Beds of dwarf oysters also occur, resembling *Ostrea hebridica*. The series is comparable in its main features with the Great Oolite of Strathaird. In Strathaird (3) the Great Oolite consists of a thick series of—

*g.* Blue shales and mudstones, with calcareous concretions.

*f.* Smooth, muddy blue limestones, weathering buff, with beds of *Paludina scotica*, intercalated shales and bands of "beef."

*e.* Shales with small lamellibranchs (*Cyrena ?*).

*d.* Calcareous shales or shaly limestones crowded with *Ostrea hebridica*.

*c.* Black shales.

*b.* Blue sandy limestones full of small lamellibranchs (*Cyrena ?*).

*a.* Black laminated shales crowded with the same bivalves (*Cyrena ?*).

The series undoubtedly belongs to the Great Estuarine series. The lower part, with the oyster beds, is recognisable in a metamorphosed state on the east flank of Sgurr nan Each and above the west side of the south end of Strath Mor.

### OXFORDIAN.

At Strollamus (2) the shales with limestones are succeeded by marine shales with cordate ammonites; these shales must consequently be assigned to the Oxford Clay. On the

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opposite coast of Scalpay, in the valley of Allt Stapaig, the following sequence is seen, the beds dipping E.S.E. or S.E. as at Strollamus:— Mr. Wedd.

| | | Feet. |
|---|---|---|
| Cretaceous | Metamorphosed cherts (?) sandstone passing under lava. | |
| | Metamorphosed blue limestone with cherts (?) - about | 8 |
| | Blue pebbly calcareous grit with *Pecten asper* and *Exogyra* cf. *conica* - - - - - - - - - - - - | 2 |
| | *Gap of a few feet.* | |
| Oxfordian (?). or Kimeridgian (?) | Black laminated shales with indeterminable ammonites and belemnites - - - - - - - - - - | |

The ammonites in these shales, though too obscure for definite determination, on the whole somewhat suggest an Oxfordian or Kimeridgian horizon. As Oxford clay undoubtedly overlies the Great Estuarine series at Strollamus just opposite, it seems that these black shales probably belong to an Oxfordian or Kimeridgian horizon. In Strathaird (3) a thick series of grey micaceous shales, with thick calcareous-micaceous shaly sandstones in the lower part, cover the Great Oolite and underlie nearly the whole of the Tertiary lavas. At the base, a conglomerate of large round pebbles of white quartzite or metamorphosed white sandstone in a matrix of calc-shaly-mica-sandstone sometimes occurs. In the lower beds, cordate ammonites are locally abundant, together with large belemnites, *Pecten fibrosus*, occasionally a large *Gryphæa*, and much fossil wood. These beds undoubtedly belong to the Oxford clay, but as no fossils were found in the upper part, it is uncertain whether any Corallian or Kimeridgian horizon is present. At the top, in one place, a small outcrop of blue limestone was seen, gritty below, with pebbles of sandstone of local Oxfordian type.

## CRETACEOUS.

*Scalpay.*—From the south of Scalpay (2), in the valley of Allt Stapaig, fossils from the thin grit above mentioned as overlying the black shales with ammonites were submitted to Mr. Newton and Dr. Kitchin, who at once suggested the resemblance of certain Pectens to *P. asper* of the Upper Greensand. This determination has since been confirmed: casts of an *Exogyra* seem to belong to *E. conica*, and a *Spondylus* may also be represented by casts. There is no doubt as to the Cretaceous age of these beds. The overlying blue limestone bed can be traced far inland in Scalpay, where it is pinched in between the granophyre and the Torridon Sandstone.

A similar blue limestone overlies the Oxfordian shales at Strollamus and may also be Cretaceous, but this needs confirmation. The same may be said of a bed of limestone seen in one place to overlie the Oxfordian shales of Strathaird (3).



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Mr. Clough. *Isle of Skye.*—On the south coast of Skye a small patch of Mesozoic rocks emerges from beneath the plateau basalts between a quarter and half a mile of the foot of Allt nan Leac. This patch lies on the north side of the Sound of Soay and a little west of that referred to in previous years by Sir A. Geikie* and Mr. Harker.† It includes a considerable thickness of the *Gryphæa* beds of the Lias, and, above these, come red and green, apparently glauconitic sandstones, with occasional pebbles. In some sections the sandstones appear unconformable to the *Gryphæa* beds, but in others they are conformable. In the best section they appear to be conformable, they are about fifty feet thick, and are overlain by a chert-grit horizon, about three feet thick, in which are thin courses and lenticles of chert embedded in a gritty rock. When examined with a hand lens the chert shows many spicules and other remains of micro-organisms. Above the chert-grit horizon come two or three feet of shale with small lumps of dark chert.

In one place near the exposures of chert *in situ* there is an agglomerate which probably belongs to a small volcanic vent older than the plateau basalts. In the agglomerate there are many lumps of chert like that *in situ*, and containing similar spicules and micro-organisms. There are also many pieces of chert (?) with red cores.

Mr. E. T. Newton has examined thin slices of the cherts from the beds *in situ* and also those in the agglomerate, and he finds them very similar. The organic remains are much obscured by chalcedonic deposits, but it is clear that besides the abundant sponge spicules, foraminifera are present, both Textularian forms and others, including *Globigerina* (?). Some of the specimens also show fragments of echinoderm plates and serpula tubes. Mr. Newton considers there is little room for doubt that the cherts are of Cretaceous age, and that they have a closer resemblance to Greensand chert than to those discovered in Arran.‡

Dr. G. J. Hinde has also examined the specimens and agrees with Mr. Newton's views.

The nearest rocks of Cretaceous age that are at present known occur under the plateau basalts of Morven and Mull, at distances of forty and fifty miles.

Mr. Wedd. *Geological Structure of the Secondary Rocks of Skye.*—The above rocks seem to be arranged as follows:—Near Sconser (1) the strata are thrown into an anticlinal fold with axis running E.N.E. It is intersected by numerous faults generally with north-west direction and north-east downthrow. At Strollamus (2) the lower beds have a general E.S.E. dip from off the granophyre of Glas Bheinn Bheag, and their general dip is maintained throughout the local Jurassic series; several faults occur, but their position is often conjectural owing

* *Summary of Progress* for 1898, p. 137.
† *Summary of Progress* for 1899, p. 142.
‡ *Summary of Progress* for 1900, pp. 123, 169.

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to the presence of much drift. In Strathaird (3) the Jurassic rocks are almost free from faults, except in the north, where there is much faulting. On the west side of the peninsula an important fault runs from the east side of the Camas Fhionnairaidh N.N.E. up the valley of Abhainn nan Leac. It throws down Great Oolite on the east against Torridon rocks and overlying Lias on the west. It is evidently pre-Tertiary and post-Jurassic. East of it, throughout Strathaird (3) the Tertiary lavas rest on Oxford clay or slightly overlap on to the Great Oolite, while west of the fault the lava lies on Lower Lias or Torridon Sandstone. The fault has considerable stratigraphical significance, for throughout the south of Skye, its line of continuation to the N.N.E. marks the re-appearance of Trias and Lower Lias on the west. This fault truncates the western side of a shallow syncline, which occupies the greater part of Strathaird. West of the fault a narrow anticline runs along the west flank of the valley of Abhuinn nan Leac and further north along the east flank of Sgurr nan Each and beyond it. West of the anticline another syncline is shown in the Lias of Blath Bheinn. Between Loch Slapin and Loch Eishort the Trias and Lower Lias lie in a gentle syncline. Mr. Wedd.

## TERTIARY.

*Igneous Rocks of Skye.*—Mr. Harker was occupied during the field-season chiefly in mapping the basaltic plateaux on the west side of the Isle of Skye, between Loch Bracadale and Loch Brittle (Sheet 70, one inch). The area surveyed during the year on the western side of Skye forms part of an extensive region, throughout which like physical conditions rule. This region consists of an assemblage of deeply eroded plateaux carved out of the Tertiary basaltic group, which is a succession of basic lavas alternating with basic sills. It is thus a country of strong relief, but with extremely little variety of lithological characters. The climatic conditions, determined by the situation and the prevailing winds, are also strongly marked. The precipitation is very heavy, and storms are frequent, but the winter temperature is not severe. Mr. Harker.

Except where escarpments or crags of the more resistant rocks break through, the surface of the country is in general covered more or less thickly with peat. This covering has in great measure protected the subjacent rocks, which had previously been stripped and scoured by the ice of the glacial period, and it results that over most of the country, soil and subsoil are alike wanting. This moorland ground is given over to sheep-farming, and affords good pasturage. The slopes are roughly drained by surface cuts, where the shape of the ground is favourable, but the more level stretches, which form the flat watersheds and border the principal streams, are in the condition of bog. The peat is cut for fuel, but at present only by the crofters for their own needs. Reclamation has never been attempted except on a very small scale, and there is little prospect of any successful effort in this direction.



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Mr. Harker. Cultivation of any kind is practicable only on certain narrow strips of the lower ground. On the slopes of some parts of the main valleys, and also sometimes of the narrower sea-lochs, which are submerged valleys, the boulder-clay attains some thickness, and comes to consist of a reddish loam, or sandy clay, representing the waste of the basaltic rocks. Most of the crofts occupy these situations, while others are placed on the relics of raised beaches which fringe some sheltered portions of the coast. Potatoes and oats are raised; the latter a scanty crop, which ripens late, or in some years not at all. The small size of some of the crofts, and the inequalities of the surface, render the use of horses for ploughing difficult in many cases, and the ancient *caschrom* or foot-plough may still be seen at work in the more remote places. The manure in general use is sea-weed. Owing to the heavy annual rainfall in this region the soil speedily becomes robbed of its more soluble constituents, and in any attempt at cultivation of a systematic kind, the choice of suitable fertilisers would be a prime condition of success.

Here, as elsewhere, the volcanic group is found to consist of numerous alternations of basic lavas and intrusive sills, also of basic composition. The lavas present somewhat more variety than in the districts formerly mapped. The amygdules in them sometimes attain a large size, and contain a profusion of zeolitic minerals, often very perfectly crystallized. Another interesting feature is the not infrequent occurrence of bands of red clay (plinthite) due to the surface of a lava-flow having suffered subaërial weathering before it was covered by the next succeeding flow. Only rarely is the monotony of the succession broken by lenticular patches of volcanic agglomerate, indicating the neighbourhood of small vents now concealed. In one coast-section, near Dùnan Earr an Sgùirr, occurs a fluviatile deposit, some thirty feet in thickness, marking part of the course of one of the rivers of the volcanic epoch, and consisting of alternations of conglomerate and bedded tuff. The pebbles are of granite and Torridonian grit, rocks nowhere exposed in this part of Skye.

The regularly stratiform intrusive sills of dolerite intercalated among the lavas make up more than half of the total thickness, and, owing to their superior durability, form all the prominent features of the landscape. They have in this district a very general vertical prismatic jointing. In particular, the isolated hills Preshal More and Preshal Beg, near Talisker, afford a magnificent display of regular columnar structure.

The great majority of the sills are not porphyritic in the ordinary sense, but some enclose sparingly scattered crystals of felspar of conspicuous dimensions. One sill of peculiar character is well exhibited in a small isolated hill (crowned by a Dùn) about two miles north of Talisker. It is about 100 feet thick, and the upper and principal portion is crowded with large porphyritic felspars, but lower down these become rarer, and at the base they disappear entirely, while the rock assumes in other respects a different character. A comparison is suggested with certain

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composite double sills formerly noted on Roineval and elsewhere; but in the present instance there is no sharp dividing line between the upper and lower portions of the sill.

Mr. Clough. While mapping the small area of Liassic and Cretaceous strata already referred to (*ante* page 146) as occurring on the north side of Soay Sound, Mr. Clough found an agglomerate with fragments of chert, containing sponge spicules and micro-organisms similar to that found *in situ*, near at hand, and which Mr. Newton considers to be probably of Greensand age. Mr. Clough is of opinion that the agglomerate "belongs to a small vent older than the plateau basalt." In addition to the fossiliferous cherts, the agglomerate contains many pieces of chert with red cores, the exact nature of which is doubtful.

*Island of Soay.*—The intrusive rocks in the Island of Soay are regarded by Mr. Clough as of Tertiary age. Perhaps the earliest intrusion is the small elongated mass with flattish top which forms Dubh Sgeir, which is a peridotite. It is in part crowded with inclusions of troctolite, some as much as 18 inches long, and is crossed by two N.N.W. dykes.

The other intrusions form dykes, running N.W. or N.N.W. as a rule, or sills. Many of the dykes and sills are rich in olivine, and some of the sills consist of dunite or picrite. These highly basic rocks frequently cut others of dolerite or basalt.

There are a number of sills of porphyritic basalt, and in these the felspar phenocrysts near the centre are often two or three inches long, and one or two broad. Rarely they are as much as eight inches long, and four broad. These phenocrysts invariably diminish in size near the margins of the sill, and for three or four inches next the selvage they usually disappear. This seems to indicate that the phenocrysts are not strangers in the rock, but have been developed *in situ*. Similar phenomena are observed on the course of a long dyke of porphyritic basalt which crosses the E. side of the island in a nearly N. direction.

Near several of the intrusions the Torridonian grits have been partially vitrified into buchite.

Messrs. Peach, Wilson, and Muff. *Inverness-shire and Argyleshire.*—Dykes with a general N.W. and S.E. trend are more or less numerous in all the areas mapped in this region during the season. These vary from highly basic olivine basalts to trachytes and even rhyolites. As they traverse all the rocks, as well as most of the structures above described they are considered to be of Tertiary age.

A few basalt or dolerite dykes of this age were met with by Mr. Wilson in the area mapped by him north of the Great Glen.

Mr. Muff traced dykes of two types, viz:—dolerites and hornblende-andesites, across the northern end of the island of Lismore. The relative dates of intrusion of these two types is doubtful, but Mr. Muff formed the impression that at least one of the andesite dykes traversed a dolerite dyke.

In the district south of Oban (Sheet 45) dykes of this age become more numerous. East of Kilbride they all appear to be basic in composition; but to the south of Loch Feochan there is

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Messrs. Peach, Wilson and Muff

a belt of country about a mile wide where compound dykes occur, in which successive rocks of increasing acidity from olivine basalt up to rhyolites have welled up one and the same fissure. Several of the fissures can be shown to have been used as an escape for gases after they had been filled by one or more of the earlier molten intrusions, as they are partially filled with agglomerate and tuff made up of thin fragments of these rocks as well as those of the walls of the fissure, and through this agglomerate some of the more acid rhyolites can be seen to have risen. A very good example of such a dyke is exposed within a few yards of the road along the south shore of Loch Feochan, about one-third of a mile from its head. The oldest rock filling the fissure is an olivine basalt. This is pierced by a massive dolerite dyke which exhibits chilled edges against the basalt. The dolerite and the basalt are traversed by fissures filled in with agglomerate of their fragments and lastly a dyke of rhyolite with double pyramids of quartz and showing fine fluxion structure along its edges, cuts both the basalt and the agglomerate.

One of these compound dykes, stretching from the head of Loch Feochan to near the head of Loch Scamadale and extending further south with the same trend, swells out at irregular intervals into a succession of wide internodes partly filled with fragmental and partly with molten materials, which evidently represent a series of volcanic vents arranged along the line of fissure. One of these vents was observed by Mr. Symes and reported on previously. (*Summary of Progress* for 1898, pp. 153, 154.)

In several instances the trachytes and rhyolites form simple dykes which traverse the andesite lavas of Lower Old Red Age, which form the "rocks of the country." In others these acid dykes are seen to converge with basic ones and unite to form compound dykes like those described above.

Mr. Kynaston

In the south-western portion of Sheet 45 the Lower Old Red lavas are intersected by numerous Tertiary dykes, mostly with the direction N.W. and S. E. The larger proportion of these belong to the dolerites and basalts, while along a certain zone a set of acid dykes have also been mapped. The basic intrusions are exceedingly numerous and vary greatly in breadth. The breadth, too, of an individual dyke often varies considerably, and their course may be sometimes diverted from the normal along older lines of faulting. Petrologically the rocks vary from a medium-grained dolerite to olivine basalt, or tachylite in thin bands. In some places a more felspathic type of dyke occurs, suggesting affinities to an intermediate type, such as trachyte. Compound dykes, consisting of two or three varieties of intrusion, running side by side in the same fissure, are common.

The acid dykes are well seen in the Loch Scamadale area. They are mostly pale grey felsites or rhyolites, occasionally with porphyritic quartz and felspar, but often too decomposed for satisfactory examination. They exhibit a well-marked flow structure, and often break up, on weathering, like a mass of slate, parallel to the wall of the dyke. They frequently split up the

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basic dykes, or form compound dykes along with them. A well-marked line of such compound intrusions runs along the course of the Braglenmore burn, south-east of the head of Loch Scamadale, and is continued to the north-west in the direction of Kilmore in Glenfeochan. (*Ante* p. 150.) Along this line a feature of special interest is the frequent occurrence of masses of ash and agglomerate, consisting of fragments of basalt, felsite, and andesite, evidently indicating a line of volcanic vents of an explosive type. The ashy material occurs in roughly oval-shaped masses, breaking through the andesites, or as bands bordering the acid dykes. Occasionally the ash is seen to be cut by the acid intrusions. Mr. Kynaston

## Kilmartin District.

*Kilmartin District.*—In Kilmartin district, lying between Loch Avich and Loch Crinan, mapped by Messrs. Peach, Wilson and Muff, during the season, basic dykes of this age with a generally N.W. and S.E. trend are extremely numerous. In the northern half of the area as many as thirty may be crossed in a traverse of a mile in aN.E. and S.W. direction. They vary in thickness from several yards to a foot or so, and in texture and composition from coarse-grained olivine-dolerites to fine-grained rocks, which probably include andesites. Some of the more basic varieties show tachylite margins, and some are vitreous throughout. Many of the more andesite-like dykes have glassy cores, with a more or less broad selvage of rocky texture; but a few are glassy throughout. That they are not all of one and the same date of intrusion is shown by the fact that at Port an Deora, a little to the N.W. of Duntroon Old Castle, Mr. Wilson observed a N.W. dyke which cuts through another dyke of coarse dolerite which, in this part of its course, trends nearly E. and W., the later dyke showing chilled edges against the dolerite. Compound dykes also occur. Messrs. Peach, Wilson and Muff.

Mr. Muff observed one of the less basic dykes to converge with a dolerite dyke and run beside it for some distance within the one fissure without crossing the latter. Two compound dykes were traced by Mr. Wilson inwards from near the head of Loch Craignish, one through Loch Fearphuirn and the other through Strome, which are believed by him to be the continuation of two dykes mentioned in last year's *Summary* by Mr. Symes as crossing the Craignish Peninsula on the other side of the loch.*

*Alteration produced by the Tertiary Intrusive rocks in Skye.*—Mr. Harker has supplied an account of the dedolomitization of the Cambrian dolomites of the Strath district of Skye by the Tertiary Plutonic masses. (*Ante* p. 131.) Mr. Harker.

Mr. Barrow also furnishes an interesting account of the effects of the Tertiary dykes upon the clastic mica flakes in the Lias clays of the Heast district. Mr. Barrow.

* *Summary of Progress* for 1900, p. 127.

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Mr. Barrow. The Lias shales of Skye, like those of Yorkshire, contain numerous large flakes of mica. They are so much cut up by dolerite dykes that it interferes with the mapping of the area. The effect upon the micas in the shales, close to their contact, is similar to that produced upon the micas of the Yorkshire Lias by the Cleveland dyke, only, in the present case, a dyke 10 yards across destroys the micas for at least 6 inches from its edge, which is more than that produced by the Cleveland dyke where it is 50 yards wide. This greater alteration may be due to the igneous material being nearer its source of origin and so having a higher initial temperature; or it may be due to the fact that the intrusions were so numerous as to heat the Lias more than we suppose, and so leaving less work for each particular intrusion to do. It should be recognised that these shales may be raised to a high temperature without leaving any evidence that they have been so. Mr. Maynard Hutchings has proved by experiment that a moist clay, enclosed in a steel cylinder, may be kept at a dull red heat for weeks without the slightest sign of alteration being produced on it that can be recognised, even by the aid of a microscope. The lithology of the lowest beds of the Lias promises to be more than usually interesting; and the alteration of these beds by small intrusions seems to be equally so. A large number of specimens have consequently been collected to investigate these points as soon as time permits.

Mr. Clough. Mr. Clough observed that the Torridonian arkoses in the Island of Soay were glazed and altered along the margin of the Tertiary dykes and intrusive sills producing Buchite. Similar phenomena occur in Applecross and Islay where Torridonian arkoses are traversed by Tertiary basic dykes.

*Pleistocene, including Glaciation and Glacial deposits.*

*Island of Soay.*—In the Island of Soay there are no widespread drift deposits, but scattered boulders of rocks, chiefly freestone, granophyre and gabbro, foreign to the island, are common. There are also rare boulders of mica-schist and hornblendic gneiss. Glacial striæ are numerous, and most of them run nearly E. and W. The N.E. corner of the island, near Clachan Uaine, has been invaded for a little distance by a drift almost entirely composed of blocks, often of very large size, of gabbro and troctolite. These blocks must have travelled from the Cuillin Hills of Skye, and perhaps they were carried to their present position after the ice from the mainland of Inverness-shire had dwindled to such an extent that it no longer reached Skye.

Mr. Wilson. *Glen Nevis.*—In Glen Nevis, Mr. Wilson obtained evidence as to the amount of drift deposits which must have been removed by denudation since the later phases of the glaciation of this region. A series of pot-holes were observed on the steep glaciated cliffs that bound the gorge made by the River Nevis at a point a mile below Steall, and a short distance beyond the point to which the coaches

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run. The highest of these is 275 feet above the present level of the river. Their mode of occurrence is such that they could have been only produced by the river when it flowed at higher levels, and Mr. Wilson is of opinion that a barrier of morainic *débris* must have formed an obstruction across the gorge at this point which has been removed since glacial times, and that the pot-holes show successive stages on the removal of the *débris*. There is also evidence that the upper part of the glen was occupied by a loch which has been drained by the removal of this barrier, and which is now represented in the wider valley above, the bottom of which is filled in with alluvial terraces. Mr. Wilson.

*Lismore.*—The drift on the Island of Lismore is represented by a tough boulder-clay containing scattered stones, many of which must have been derived from the mainland. The matrix of the clay at the north end of the island is somewhat reddish, whilst towards the south-west part of the area it becomes quite black. The change appears to be gradual, and is doubtless due to the grinding up of the limestone and its incorporation in the clay during the south-west movement of the ice. The percentage of limestone boulders in the clay also increases towards the south-west. Amongst the boulders from the mainland the following have been identified by Mr. Peach:—Quartzite, porphyrite (probably of Old Red Sandstone age), Old Red Sandstone arkose (from the Great Glen), many varieties of granite, including some traversed by pegmatite veins, from the north side of the Great Glen, and also the basic edge of the Cruachan mass, Moine schist, and an agglomerate like that of Ben Nevis. The boulder-clay forms a few mounds situated on the lower ground or banked against steep limestone scarps. Two winding kames, situated half-a-mile south-west of Port Ramsay, run across the low ground in a south-east direction. Mr. Muff.

Large boulders of granite and quartzite are scattered over the hills at all altitudes. Some lie against a pedestal of limestone, which they doubtless formerly capped.

The direction taken by the striæ is very variable, but is, on the whole, about parallel to the long axis of the island, and the striæ indicate a south-westerly movement of the ice. On a small island west of Eilean Ramsay a set of striæ, running from N. 5° E., is crossed by a later set running from N. 70° E. The striæ are preserved only on the igneous rocks, and then almost always between tide marks. Some idea of the rate of the atmospheric denudation of the limestones may be gained from the fact that at low water mark the limestone is nearly flush with the striated surface of a dyke, whilst at about high water mark the striated surface on the dyke stands about one foot above the surface of the limestone. This denudation must have taken place, if not since the epoch of the 25-feet beach, at any rate since that of the 50-feet beach.

*Region south of Oban.*—In the area near Kilmore, mapped by Mr. Peach during the season, the glacial phenomena are almost entirely attributable to the later glaciation. The striæ show a general ice movement across the country from E. to W. On the high plateau between Loch Nell and the Feochan Beg, Mr. Peach.

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Mr. Peach. the striæ trend a little to the north of west, while those found in the valleys have a tendency more or less to conform to the direction of the valleys. Moraines made up in great part of schistose rocks, and granite from the Cruachan region are scattered over the plateau independently of the present valley system in such a manner as to show that the glaciers after leaving the Highlands must have coalesced and over-ridden this part of the surrounding lower ground. Loch Nell seems to have been the site of a tongue of this ice during the 100-feet beach time, as moraines are found on the terrace of the 100-feet beach which forms its present dam. Another tongue of the ice must have occupied the Feochan Beg as far down as Craigentaggart during, or since the 100-feet beach time, as moraines are found in the bottom of the valley above, which at this point is below the 100-feet level, while further down the river has cut its terraces of alluvium through the 100-feet and 50-feet beaches.

Trains of boulders are common across the area in the same general direction as the striæ. Thus north of Loch Nell there is a wide train of boulder of Cruachan granite; but perhaps one of the most striking trains of boulders is that supplied by an exposed portion of a large porphyrite dyke occurring on the hill top to the south of Glenamacrie, in Glen Lonan, from which a very conspicuous train of boulders can be traced to Torran Tuirc, near the head of Loch Nell.

Messrs. Peach, Wilson and Muff. *Kilmartin District of Argyllshire.*—In the narrow belt of ground mapped in this region during the season, stretching from Loch Avich in the north to the Crinan Sea Loch on the south, the rock is singularly bare of drift. The ice-movement over the area, as indicated by the striæ and the carry of blocks, was towards the W.S.W., with local deviations according to the shape of the ground.

The sparse glacial deposits are mostly of a morainic character, but Mr. Muff mapped some small areas in the neighbourhood of Salachary of what may be looked on as Boulder Clay. With perhaps this exception, most of the phenomena observed are attributable to the Later Glaciation, when the glaciers from the higher Highland valleys to the head of Loch Awe coalesced on the low ground and overrid the lower plateau of which the present is a portion. Moraines are common to the south of Loch Avich, on the water-shed between Glen Domhainn and Loch Awe, where they could not be laid down by local glaciers nursed within the water-shed. Boulders, foreign to the region, such as granite and schist, like those surrounding the Cruachan massif, are scattered over the area. Boulders of andesite and porphyrite like those which traverse the andesite rocks north of Loch Awe are abundant within the area.

As probably showing a stage in the shrinking of this confluent glacier, a lake terrace 200 feet above the present level of the loch is found round the S.W. or upper end of Loch Avich, of such a character and in such a position that it must have been formed when the lake drained to the S.W. into Glen Domhainn, the head of the Barbreck River. The gravels and sands of this

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terrace have been traced to the actual water-shed at about one-third of a mile to the S.W. of Maolachy on the road between Kilmelfort and Loch Avich, where the road traverses a small rocky gorge evidently cut by the water flowing out of the lake. The fine silts and sands of the terrace can also be seen near the roadside near the same spot. The present outlet of the lake shows no evidence of a barrier of moraine stuff or rock of such depth having been removed since glacial times, and the only explanation of the high terrace, which is in every way comparable to one of the terraces of the "Parallel Roads of Glen Roy," is that the barrier was due to the lower end of the lake being occupied by ice when the terrace was formed. Messrs. Peach, Wilson and Muff.

*Island of Soay.*—As might be expected from the exposed position of the Island of Soay, the material in the raised beaches is very coarse. To a large extent it is composed of boulders two or three feet long, which have been piled up in storm banks. There are small deposits of gravel as much as 60 feet high, but perhaps these were thrown up in storms considerably above the general sea-level. Mr. Clough.

*Lismore.*—The north coast of Lismore bears a well marked terrace at an altitude of about 35 feet above O.D., which doubtless corresponds to the 50-feet beach of neighbouring areas. Though usually a bare rock ledge, it is sometimes covered by water-worn gravel, containing similar rocks to those found in the Boulder Clay, in addition to many limestone pebbles. No shells have been obtained from this deposit. Undisturbed Boulder Clay reaches down to this beach, and no evidence of a higher beach was obtained. The cliffs bounding the 50-feet beach are indented by many small caves, whose walls are covered by stalactites. At Sron-na-bravibhe, in place of the cliffs there is found a curved ridge of gravel, concave towards the sea, and formed of false bedded ferruginous sand and gravel of essentially the same composition as that found on the 50-feet beach elsewhere. This ridge in cross section has a long gentle slope seawards, and a short steep slope on the landward side, where the surface drainage is obstructed and a peat moss has formed. Similar though smaller ridges, are found in analogous positions to the north and to the south of Port Ramsay. They appear to be storm beaches of the 50-feet beach period, behind which shallow lagoons may have existed at that epoch. Mr. Muff.

A lower raised beach, which is distinguished only with difficulty from a more modern storm beach, appears to be preserved only near Port Ramsay, where the coast is sheltered by small islands. Peat, besides filling shallow depressions of the Boulder Clay surface and lying behind the old storm beaches already described, occupies the site of former lochs, at the source of Allt a'Mhuilinn and again just south of the school house.

*Lorne District.*—Near Kilmore the 100-feet raised beach occupies a well-marked terrace at the foot of Loch Nell and in the angle between the Feochan Mor and Feochan Beg rivers. The terrace, partly as a rock notch and partly covered with beach Mr. Peach.

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Mr. Peach. materials, can be traced down the south-east side of Loch Feochan for some distance from its head.

The 50-feet beach is also well displayed in the same district. At Kilmore it is much covered by a coating of peat. It can be easily followed down the south-east coast of Loch Feochan close to the high road, and the rock caves along its margin are still often tenanted by tinkers and tramps who contribute the refuse of the shellfish they use as food to the kitchen middens found at their mouths.

Mr. Wilson. *Kilmartin District.*—The 50 feet beach is well marked along the seaboard from Crinan Loch to the head of Loch Craignish and also to Island Macaskan and Eilean Righ. It extends up the Kilmartin Valley to within a mile of the village, and on it rests the extensive peat-mosses of Moine Mhor and Poltalloch. This terrace is generally composed of rolled stones and gravel, and a section on the River Add, near Drumore, shows ten feet of fine horizontally-bedded gravel on top of stiff, light grey Boulder Clay.

On the east side of Loch Craignish and the two islands, the 100-feet beach is not well marked, but in the Kilmartin valley on both sides it forms a conspicuous feature, and extends as far up as the cross roads to Ford and Oban. A short distance to the west of Eurach a belt of epidiorite lies just beyond the upper limit of this beach and extends across the valley. This band has numerous pot holes, which must have been formed during the 100-feet beach period, and when the surplus water of Loch Awe passed down the Eurach valley. At Slockavullin and near Balameanoch, clay pits have been wrought in this beach deposit and a fair quality of bricks and tiles produced.

Messrs. Muff, Peach, and Wilson. *Economic Minerals.*—The largest area of limestone is to be found in Lismore. At present it is only burnt at Port Ramsay, whence it is taken away in boats, and there is an annual output of about 600 tons; but the supply is practically inexhaustible. Limestone has been more or less locally wrought and burnt all over the Kilmartin area, but at present it is evidently cheaper to import lime from Lismore and other places than to produce it on the spot.

The epidiorite sills afford the best building stone in the Kilmartin region. Any granite used in this part of the country is obtained from boulders. The limestone and quartzite are used considerably for drystone dyke building.

Road metal is everywhere easily procurable and of excellent quality, owing to the innumerable basalt and dolerite dykes that traverse the region The little dark limestone that is found in the black schist, especially where it has been slightly altered, near one of the basalt dykes, also affords good road metal.

A brick clay was formerly used at Slockavullin, one mile south-east of Kilmartin. It appears to have originated from the alluvium of the Slockavullin stream, where it has been dammed back by a spit of the 100-feet beach. The clay appears to be exhausted or no longer workable.

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In this district the Moine Mhor and Poltalloch peat mosses afford an almost inexhaustible supply of fuel. Some years ago Lord Malcolm of Poltalloch erected plant for converting the raw peat into peat coke. The machinery came from Sweden and the experiment was highly successful, but on account of the small size of the plant the financial results were not satisfactory. This year the machinery has been removed to the south side of the Moine Mhor, and, with additions, it is to be employed on a much larger scale in the production of coke for the iron smelting works which are being built near Island Add Bridge. Mr. Wilson.

More than a hundred years ago several small veins of copper were wrought at the top of the hill, and close to the old hill road which crosses from Kilmartin House to old Poltalloch. The veins intersect the large epidiorite sill, and these have been only opened up by shallow trenches and a small water level, about twenty yards long, with connecting shaft of similar length, to the hill face above. The ore obtained was chiefly malachite with a little black oxide of copper and manganese. The leading vein is about four feet in breadth and the walls are lined with calcite and quartz crystals. The vein face at the end of the water level is cemented up with stalactitic material and quite concealed.

## 3.—East Highland District.

Dr. J. Horne, F.R.S., District-Geologist (acting).
Mr. G. Barrow,
Mr. E. H. Cunningham-Craig, } Geologists.
Mr. J. S. G. Wilson,

In the Eastern Highlands, Mr. Barrow continued field-work in the district of the Tarf Valley, in Atholl Forest, in Sheet 64 one inch; and Mr. Cunningham Craig surveyed a tract lying immediately to the north in the Glen Feshie Forest and in the neighbourhood of Newtonmore. In the autumn Mr. Barrow completed the mapping of a small unfinished area near Balmoral in Sheet 65 one inch. In connection with the publication of Sheet 55 one inch, Mr. Barrow re-examined the Garry section north of Blair Atholl; Mr. Wilson drew additional boundary lines in Strath Tummel; and Mr. Craig mapped in great detail the area extending from a line north of Pitlochry to near Blair Atholl.

*Tarf District.*—Mr. Barrow reports that a considerable portion of the area drained by the Tarf, on the north side of the Tilt valley, in Sheet 64, is composed of typical Moine-gneisses which, on the whole, closely resemble the gneisses of the Bynach area, described in a previous report. The tendency to local variations in the gneisses of the latter, has also been observed in the Tarf area. There are, however, some differences between the rocks of the two areas. The colour banding so common near the Bynach is not so frequently met with in the area surveyed during the past season. Mr. Barrow.

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Mr. Barrow. The typical parallel structure is present over most of the area, but it is often shown more by the parallelism of the biotite than by any other feature. This local peculiarity of the gneisses is clearly connected with another which characterises parts of this district. The Moine gneisses often weather like a fine-grained granite—a feature which is not confined to a few small bands; indeed large masses of rock at a short distance off so closely resemble granite in appearance that the rocks had to be carefully examined to make sure that they were not really original igneous material intruded in a sill-like form in the Moine gneisses. It was found that in this type of rock a vast number of small patches had lost all trace of parallel structure; indeed the transition to the part of the rock showing the normal parallel arrangement of the biotite is so gradual, that a series of specimens has been collected to investigate the structure and composition of this type of material.

While over much of the district the arrangement of micas and the colour banding, when well marked, is parallel to the original bedding of the rocks from which these gneisses have been formed, there is rather a broad belt in which this is not the case. In this belt the gneisses show the typical thrust-plane structure of the Southern Highland grits. These thrust-planes cut the rocks intersected by them into thin phacoids in which the relation of the main axis of deformation to that of the least is largely determined by the fineness or coarseness of grain of the sandstone or grit before deformation. A grit is cut into much shorter and thicker lenticles than a fine green sandstone or greywacke; and from the tenuity of the phacoids in these Moine gneisses we at once know that they were originally very fine grained rocks, containing a considerable amount of chloritic material. The cause of this deformation has been well established. It is connected with the trend of the dyke-like intrusions that supplies the material of the sills of epidiorite in the Southern Highlands.

While the bulk of the Moine gneisses must have been originally very fine sandstones, here and there this material was replaced by what was originally more of the nature of a shale. Though now altered to an oligoclase-biotite gneiss, there is no doubt that it was originally a shale, for it still retains the minute puckering which is distinctive of altered shales as opposed to sandstones, which never show this feature except at their junction with a softer rock.

A special feature of the Tarf area is the frequency with which the junction of the gneisses with the Central Highland quartzite can be observed, and as a rule there is a very gradual passage from one rock to the other. Still more important, however, is the clear evidence that the whole of the Moine gneisses in the region examined by Mr. Barrow lie between the quartzite on the one hand and the Little Limestone (Tremolite limestone of Braemar) on the other. They are, in fact, only a small zone in the Highland rocks.

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The details of the evidence in the Tarf area are complicated by the interruptions due to the great intrusions of Newer Granite in the district, but there can be no doubt that these gneisses do lie between the two rocks named above. Mr. Barrow.

This conclusion is further strengthened by the evidence in the Falar area, which may here be described.

In Glen Mhor, a little below the junction with Glen Bheag, a remarkable group of rocks is seen which have been called "hone-stones," as they were for many years used as hones, and people came to this locality from great distances to get them. Similar rocks are known to occur at this horizon in many localities. They are clearly seen to lie between the quartzite and the Little Limestone (Tremolite limestone of Braemar). The dominant constituent of the group is a thin banded fine-grained brownish rock, essentially composed of a granular admixture of quartz and felspar, through which a considerable amount of brown mica is disseminated. The mica occurs parallel to the banding of the rocks and intensifies the evenly bedded aspect of these "hone-stones." The brown bands are often separated by thin partings of more micaceous material, clearly mud or shale originally, which was "cross-cleaved" prior to crystallisation: a phenomenon identical with that seen in the Silurian rocks of the north of England. The occurrence of these "cross-cleaved" bands, persistently parallel to the brown bands, is clear proof of original bedding in these crystalline rocks. In addition to these constituents, there are also a few thin bands of pink weathering granular material, and more rarely a few white layers. The composition of the latter is of importance; for while there is hardly any white mica in the brown bands, there is usually a considerable amount in the pink and white material. There is still another distinctive feature of the group. The brown beds are divided up into thin layers by extremely persistent films of what was originally chlorite, but is now more or less completely altered to a "felt" of brown mica. Thus it will be seen that these beds are a singularly well-marked group in which parallel banding is the dominant feature, and if we start from the edge of the quartzite we see at once that they are essentially a passage material between the quartzite and the dark shales, on the reverse side of the Little Limestone. These rocks, when traced, frequently undergo local changes in composition, becoming more or less siliceous, but each individual band of the whole group undergoes this change; no band is cut out and replaced by material of different composition.

In the bed of the Tilt, just below Pool Tarf, the "honestone phase" of these rocks is exceptionally well seen; but here they are slightly thicker as a whole, and this slight thickening is well shown by the cross-cleaved bands. At this point they occur exactly on the line of rapidly increasing alteration, to which attention has been drawn in former reports and which will be referred to again in the sequel. From this locality the rocks become rapidly more crystalline, and this change can be followed on bare rock onwards to Pool Tarf, and up the gorge of the Tarf,

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Mr. Barrow. where they rapidly pass into the typical Moine-gneiss of the great area to the north. It is fortunate that these beds can be so quickly traced from the less altered to the far more highly crystalline condition without the intervention of any infold of other material to break the continuity of the evidence.

*Bynack District.*—Confirmatory evidence is obtained in the Bynack area, where the Moine gneisses have an almost identical structure and composition with that of the "honestones." The typical grey gneiss, by far the most important member of the group, contains little and often no white mica, while the pink and white bands invariably do so, as in the "honestones." The structure is essentially granular in both rocks, but the grains are much smaller in the "honestones." The biotite in both rocks has essentially the same colour, being intermediate between that of Haughtonite and the rich red contact mica.

*Struan District.*—The widening of the Highland Railway above Struan has exposed admirable sections of the Moine gneisses. As usual they show the parallel banding due to layers of different composition, as well as the parallel arrangement of the micas. The dominant constituent of the group is the grey well crystallised gneiss, which is associated with a subordinate amount of pink and white gneiss. In addition cross-cleaved mica gneisses are present, but these form quite a small proportion of the whole. The increased thickness of the latter when compared with the "honestones" is even more marked than in the Tarf area. The examination of the whole series of sections suggests that there is only one moderately thick bed of cross-cleaved mica gneiss, for wherever visible it is apparently always accompanied by the same grey, pink, and white bands, though there is often a certain disparity in the relative thickness of these three components. The railway sections show that though there is a steady dip in one direction, the same beds are constantly repeated. It is here seen that at short intervals the rise of the beds, owing to the persistent dip, is counteracted by a short, nearly vertical, roll over. This roll over can be made out in the river sections, but its effect in individual cases can rarely be traced with the clearness made possible by these new railway cuttings. These rocks in Glengarry have long been known as the Struan Flags from their flaggy mode of weathering —a feature which is largely due to the original presence of felted chlorite (now biotite) films, as in the "honestones." These films are often a specially marked feature of the Struan or Garry gneisses. As usual there is a considerable amount of variation in the composition of these rocks, but, broadly speaking, it is much less pronounced than in the area farther east. It may be noted that before crystallisation, the original beds in this district underwent far more mechanical deformation than in the Bynack and other areas, which has resulted in the production of a greater amount of white mica,

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Mr. Barrow.

The further examination of the deep sections in the Falar area by Mr. Barrow has thrown much light on the other members of the succession which are there associated with the parallel banded series or Moine gneisses.

With regard to the succession, whether ascending or descending, it is as follows, *when complete* :—

1. The altered parallel banded calcareous shales.
2. The Main Limestone.
3. The dark or leaden schist.
4. The Little Limestone (locally the Tremolite limestone).
5. The parallel banded series (honestones, etc.).
6. The Central Highland quartzite.

(1) The altered parallel banded calcareous shales are among the most easily identified rocks in the Highlands, and are never absent, to my knowledge, from any valley between two quartzite mountains broad enough to show the whole succession. They occur at intervals from Falar to Braemar, and where some of these bands have a suitable composition they always have a peculiarly hornfelsed character. The thicker and more calcareous bands contain white pyroxene and are far more coarsely crystalline—a feature which is characteristic of the outcrops between Ben Vuroch and Braemar. Nevertheless, within certain limits, these bands vary incessantly in total chemical composition.

(2) *The Main Limestone.*—This can generally be recognised by its purity and persistent thickness. When specially siliceous, as in Glen Mhor, every member of the succession with which it is associated is more than usually siliceous, except of course the quartzite.

(3) The dark or leaden schist, which covers such large areas, varies considerably in composition in different localities. In its normal dark phase this schist may be divided into certain well-defined zones that have been traced over a large area. A little way from the edge of the Main Limestone it contains a large amount of kyanite, in regions of moderately high alteration, but this gives place to other silica aluminates, such as sillimanite, andalusite, or cordierite, in the areas of highest alteration. Nearer the Little Limestone we have the rock with felspar (or hornfels of Glen Callater), and the zone, with large plates of twin-chlorite. In many cases, these schists, originally rich in chlorite, contain a peculiar association of micas; the normal white mica does not occur in them. No part of this schist, in all this area, ever possesses the dead-black colour, accompanied by disseminated graphite that so often characterises part of the true graphite schist.

(4) *The Little Limestone.*—In tracing the changes that occur in this sedimentary series, it has been found that this limestone is altered to a Tremolite-rock only when the schist next it is dark in colour and associated with the twin-chlorite-rock and the felspar-rock. In varying phase of composition it occurs over a very large area. North of the Tilt it is usually an intensely hard, green, flinty rock, containing a very variable amount of garnet, and a smaller quantity of idocrase. The green colour is due to disseminated



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Mr. Barrow. green pyroxene. In the Tilt valley it is less highly crystalline, but, being frequently exposed in the river bed, we are able to note how very variable in composition the rock is. It is doubtful if green pyroxene occurs here, but garnet and a little idocrase are sometimes found. In the Glen Mhor area it is usually a rather siliceous limestone, with lenticular siliceous ribs, somewhat resembling those seen at one locality in the Main Limestone. In this phase the Little Limestone occurs in a great number of places, but, previously, it was regarded as the base of the Main Limestone, caught in a fold. On this supposition the structure of the ground was difficult to understand, but the map is at once rendered intelligible when we know that there are two limestones, and not one. About four miles south of Braemar this bed again occurs, where it contains numerous garnets, but no pyroxene. About the north side of the Dee it re-appears as a green, flinty rock where next the parallel banded series. Again, east of Balmoral, the same flinty green rock, with garnet and a little idocrase, is seen, but nearer Badvo the green portion is a mere film, and the main part of the rock is now built up of radiating spherical masses of Tremolite, associated with some calcite and a micaceous mineral. Throughout its whole course it shows liability to change in chemical composition, like the parallel banded series.

(5) The parallel banded series has already been sufficiently described, but the zone shows better than any other the fact that these rocks, while incessantly changing, also incessantly revert to the normal type. Thus the flaggy hornfels of Glen Callater is the flaggy hornfels of Glen Fender, near the mouth of Glen Tilt, and the hard, parallel banded biotite schist next the Little Limestone in Glen Mhor was obviously the same material, originally, as the hard, banded biotite schist to the east of Balmoral.

(6) *The Central Highland Quartzite.*—This zone furnishes remarkable evidence bearing on the original thickness of the Highland series. The succession is as follows :—

(*a*) The fine white edge of the quartzite.
(*b*) The quartzite banded by fine lines of heavy minerals.
(*c*) The porous quartzite.

The porous quartzite, which is between six and eight feet from the fine white edge of the mass, is very easily recognised from the holes left in it owing to the decomposition of rather large and scattered felspar pebbles. (The remnants of these in the holes were clearly seen both by Mr. Horne and myself.) Now this band, according to Mr. Barrow's observations, runs through almost every great quartzite mountain, and the evidence suggests that these three zones together form the greater part of the original mass. Ben y Ghloe is formed of quartzite, folded on itself to the exclusion of every other rock. The folds in this mountain are 2,400 feet deep at least, and there is not a bend or buckle in the folds, while the bedding planes and limbs of the folds have a persistent dip of 60° for nearly two miles. The porous quartzite occurs repeatedly in this mountain, as it does again in another huge mass of quartzite seen in Cairn Righ, farther east. As

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already stated, its mode of occurrence is such as to suggest that there is probably not much more than the three bands, a, b, and c, present, and we are led to the conclusion that these enormous masses of quartzite are built up by the isoclinal folding of a bed that may be not more than twenty or thirty feet thick originally. Mr. Barrow.

At intervals, across the whole area known to Mr. Barrow, parts of the series are missing. This is clearly shown when the Main Limestone is in contact with the quartzite. The phenomenon suggests that we are dealing either with non-deposition, due to current action, or with local erosion, equally due to current action. The probability is that in such a series we are dealing with both, and the mode of occurrence of the "Boulder-bed" is strongly suggestive of local erosion.

The further result of the work in this district shows that a line or belt of rapidly increasing alteration can be traced from the upper part of the Dee to a point a little north of Blair Athol. This belt passes through the great mass of basic diorite in Glen Tilt, without being the least affected by that intrusion; and the line can again be shown to be independent of Newer Granite intrusions, as proved in the Bynack area, where the Newer Granite is comparatively rare. From Braemar a similar line roughly corresponding with the Dee can be traced for about four miles down the river. It has been shown by the rock sections that the increase in crystallisation to the N. of this line becomes less and less marked, till in the area east of Balmoral it is very slight and extremely gradual. This progressive metamorphism is intimately connected with the problem of the widespread hornfels type of alteration which will now be described.

The evidence on this interesting question now points clearly to a definite cause for this alteration. This type has been found in the Falar and other areas, where the metamorphism cannot be attributed to Newer Granite alteration. It occurs repeatedly between Ben Vuroch and Braemar; and is mainly confined, when well shown, to two beds. The first of these is the banded calcareous shale next the Main Limestone. In this, as already stated, the bands are almost glassy at times, and the constituent grains are there very small.

The other bed is the Flinty-biotite schist, next the Little Limestone, which occurs repeatedly and has in no case been produced by Newer Granite alteration. The feature of this rock, too, is its fine grain. It clearly consisted originally of an admixture of fine quartz, some felspar, and a considerable amount of chlorite. The fine chlorite acts at a specially low temperature on the quartz, and the rock becomes indurated and, unless the material be afterwards crushed, retains this induration, accompanied by a finely crystalline condition. At times another rock shows this hornfels type of alteration: but in this case it is not so finely crystalline. This is the felspar-hornfels of the Glen Callater type, which occurs twice in the Falar area. A section shows that this is even a better example of hornfels alteration than the Glen Callater rock. It is at least fifteen miles from the Lochnagar granite and a great distance from any Newer Granite intrusion,



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Mr. Barrow. while the Glen Callater rock is actually inside the Lochnagar granite. It is thus perfectly clear that the hornfels structure of this rock has nothing to do with the Newer Granite mass of Lochnagar, and that this gneous mass has produced practically no effect on the Highland rocks, the crystallisation of which is obviously pre-granitic.

Turning now to the area east of Balmoral there is no sign of increasing alteration in the Highland rocks as we approach the eastern margin of the Lochnagar complex. The lines of very slow increasing alteration trend east and west at right angles to that margin. With material of similar composition, it is found that these rocks possess a common feature and one that distinguishes them from all others in the Highlands. The true hornfels rocks, when in an area of high or moderately high alteration, are distinguished by the occurrence of a great number of minute flecks of biotite distributed through the rock. (This mineral usually posseses a rich brown colour.) The evidence already obtained makes it practically certain that this flecking is due to the (early) action of the chlorite on the quartz which produced an induration that made it difficult for material to migrate. This dissemination of flecks of biotite never occurs in a thoroughly schistose or gneissose rock.

*Newer Igneous Masses.*—A considerable mass of Newer Granite has been mapped on the north-west side of the Tilt Valley. Part of this area was formerly surveyed by Mr. Dakyns, and specimens were collected which have been described by Mr. Teall. Briefly, the complex consists of variations of diorite, the greater part of which is distinctly basic, and modifications of granite, the bulk of which is markedly acid and contains much free quartz. But there are some phenomena of extreme interest associated with these intrusions. They are connected with the foliation of certain small intrusions, the occurrence of dyke areas and dyke-free areas, and also with what may be conveniently called the "roof" of the complex. The phenomena associated with the latter are specially interesting in view of the idea they suggest as to the mode of intrusion of the granite. The composition of the material around and above the intrusion (Quartzite and Moine gneisses) is prohibitive of the view of the formation of the granite approximately *in situ*, by absorption of the surrounding material, while the mapping of the "roof" shows that the idea of upheaval of the overlying rocks is equally unlikely. The mode of occurrence of the acid material suggests a new, and possibly in many cases a far more reasonable, explanation of the mode of intrusion of these granite masses. It is seen that acid material is injected between the roof or enclosing wall of the older diorite and the diorite itself. The mode of occurrence of these injections suggests that the acid granite did not lift the roof up, but pushed the older more basic igneous material down in many cases. It seems as if the igneous material had forced its way up one or more ducts till a point was reached where it could no longer remain fluid or plastic enough to flow. It then spread out in the form of sheet, working downwards to a warmer and not upwards into a colder environment.

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Mr. Barrow.

The portion of the great drainage area of the Tay that lies above Pitlochry varies greatly in character. One feature is common to all the minor valleys that together compose the area. They are locally covered with peat and drift, the latter being a softish clay or gravel. In consequence they all bring down a certain amount of highly micaceous fine mud and peat held in mechanical suspension.

To the N.E. of Pitlochry there are thick masses of limestone; these cause a considerable amount of lime in solution to enter the main drainage valley. A similar limestone area occurs on one side of the Tilt above Blair Athol; this again imparts much lime in solution to the water of the Tilt.

On the N.W. side of the Tilt, particularly in the Tarf Valley, are considerable masses of granite and granite drift. The latter contains a large proportion of decomposing felspar, which gives out a large quantity of soluble silica when rain percolates through this granite drift.* In flood times the water in the Tarf is almost black with peat.

The upper part of the Garry supplies a fair amount of silica, the rocks over which the rainfall passes being mainly felspathic gneisses. There is little lime in this area.

The Tummel drains a large area of granite and quartzose gneisses, much of the ground being covered with peat. It passes through two large lakes, Loch Rannoch and Loch Tummel, and, except in specially heavy floods, the Tummel water is greatly filtered and cleared of impurity in its passage through these lakes.

Mr. Craig.

*Glen Feshie District.*—In the area surveyed by Mr. Craig in the Glen Feshie district, the rock consists of Moine schists of the siliceous type, with many small intrusions, chiefly granitic.

Two types of the schists can be distinguished, but it is not possible to separate them on the field maps. The first consists of flaggy quartz-biotite-gneisses or schists, highly granulitic, and occasionally with fairly thick massive beds; these rocks contain very little muscovite, and that chiefly along planes where differential movement was greatest. The second type is much more highly felspathic and does not weather into flags, muscovite is more abundant, though biotite is still always present. On a cross fracture the beds often appear almost granitic in character.

*Newer Igneous Rocks.*—Intruded into these schists, small diorites and lamprophyre dykes and sills are seen; they are of the usual type of the newer diorites and lamprophyres of the Braemar district.

Granitic intrusions are frequent, as might be expected, in an area lying between the Cairngorm granite on the N.E., and the Beinn Dearg granite on the south. An extension of the

* A singularly perfect illustration of the quantity of soluble silica washed out of granite drift is afforded by the mass of diatomite on Duniet Moor, Aberdeen. The supply of silica for this material is derived exclusively from the great mounds of granite drift, the rain falling on the mounds percolating them and issuing charged with silica.

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Mr. Craig. Beinn Dearg (Perthshire) mass crosses the county boundary, and about two square miles of granite have been mapped on the Inverness-shire side, where it forms Meall Tionnail. This Meall Tionnail granite resembles very closely the Cairngorm granite, especially that type seen on Beinn Bhrotain, *i.e.*, very acid, with very little biotite, and fairly coarse in grain. Indeed at one part of the margin the Meall Tionnail granite is practically a binary granite, very coarse, and with a few large scattered flakes of biotite. It is coarse right up to the margin. This mass is also characterised by the absence of the much more acid intrusions which are so common in many parts of the Cairngorm mass, and by the fact that it does not seem to be affected by fault movements. From these data it appears probable that the Meall Tionnail granite represents one of the latest phases of the Cairngorm granite intrusions.

Apart from the large mass of granite forming Meall Tionnail, there are no acid intrusions of any great extent; though veins are very numerous, they never attain large dimensions. These veins vary in character considerably, aplites, fine and coarse granites, and pegmatites are frequent all over the area except in the N.W. part, where one passes gradually from an area characterised by the intrusion of plutonic rock of the Newer Granite to an area in which the intrusions have been cooled more quickly, and appear as quartz-porphyries and felstones with chilled edges. One well-marked sill has been mapped, its eastern extremity being granite, and its extension to the N. and W. being quartz-porphyry. In the intermediate area specimens ranging between granite and quartz-porphyry can be obtained; a phenomenon observed near Braemar, where the Auchindryne granite passes westward into quartz-porphyry.

The granite veins frequently exhibit coarse central zones of pegmatitic material, and sometimes have coarse pegmatite margins also, thus resembling the later vein intrusions in the granite mass of the Cairngorms.

A small part of the margin of the Cairngorm granite, east of the river Eidart was examined. It presented no remarkable characteristics, but the metamorphic rocks within half a mile of the junction are pierced by a great number of granite veins, coarse red pegmatites and pale aplites, all of which are of the Newer Granite type. There are no foliated muscovite pegmatites of the Chest of Dee type in this locality.

*Newtonmore District.*—In the area surveyed from Newtonmore, the rocks encountered are the same types of Moine schists, with minute infolds of muscovite-biotite schist in the western part of the area. The development of pegmatite veins in this area presents some points of interest. These veins vary in breadth, from an inch or two up to six feet or more. They are usually along the bedding planes, but sometimes cross them at high angles. No single vein can be traced far. In composition they are usually coarse muscovite pegmatites never showing any signs of being more quickly cooled at the margins; the crystallisation is uniform throughout. These veins never show signs of having been affected

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by dynamic metamorphism, and no contact metamorphism has taken place at their margins, but the country rock appears to have crystallised simultaneously with the pegmatite, the crystals interlocking in the most intimate manner. Mr. Craig.

When these pegmatites are intruded through rocks rich in biotite, the pegmatites contain a considerable quantity of biotite also, even to the exclusion of muscovite in thin veins, but the usual type in a quartzo-felspathic country rock, not containing much biotite, is a muscovite pegmatite without biotite.

From these facts it appears probable that segregation has taken some part in the formation of these veins, and that they are contemporaneous with the regional metamorphism of the district.

In the area surveyed in Glen Feshie, there is very little soil derived from the disintegration of rock *in situ*. The higher parts of the hills are covered with a stony rubble of the Moine schists, while the area occupied by the Meall Tionnail granite presents a surface of weathered granite blocks and sand.

The lower parts of the glen are entirely covered with sandy morainic *débris*. The greater part of the area is covered with peat which occasionally attains a depth of ten feet.

No part of the ground is cultivated, there are no quarries, and no population, as there are no inhabited houses in the area.

The water supply is abundant, but liable to be somewhat peaty during floods.

The area is part of the Glen Feshie deer forest, and the high ground and alluvial stretches along the river Feshie furnish the rough pasture most favourable to deer. A considerable number of grouse breed on the lower ground, but are not shot in this part of the forest.

To the area surveyed from Newtonmore the same remarks apply, but there are one or two houses with small patches of cultivated ground on the alluvial soil and fluvio-glacial gravels along the river Truim.

The land affords grazing for a few sheep, but its chief value is as a grouse moor, the low lying heather-covered areas affording excellent cover and feeding for the birds.

*Aberfeldy District.*—The mapping of the Green Bed outcrops south of the Tay, in Sheet 55, has been completed by Mr. Craig, and has, as usual, thrown considerable light upon the structure in this district. The presence of several important faults not previously recognised has been demonstrated, and additional evidence has been obtained regarding the flat-lying type of folding.

The progressive metamorphism northward, to which attention was called in last year's report, can now be considered in greater detail, microscopic examination of a series of specimens chiefly from the Green Beds having been made. A series of specimens taken, roughly speaking, from south to north, exhibits the increase in metamorphism strikingly. Pebbles are very conspicuous in the more southerly outcrops, while garnets are absent, the rocks consisting of biotite-hornblende schists with pebbles of quartz more or less numerous, and a certain amount of granulitic quartz and felspar in the matrix. The quartz pebbles, as pointed

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Mr. Craig. out by Dr. Flett, consist of lenticles more or less granulitized and showing all stages in the breaking down into a granular mosaic. The felspar Dr. Flett finds to be secondary, and from its low refractive index, as ascertained by Becke's method, must be either albite or orthoclase.

In specimens from outcrops farther to the north, and especially in beds of originally finer material, on which the dynamo-metamorphism has taken greater effect, a further stage in the thermometamorphism is seen. The hornblende still appears in feathery ill-defined prisms, but attacking the quartz pebbles and the granulitic quartz of the matrix. Garnets, small and idiomorphic, are common, while epidote and iron ores are also present.

A gap of from one and a half to two miles separates the outcrop of the Green Beds south of the Tay from that north of the Tay. Two specimens from the outcrop north of the Tay have been microscopically examined. These show such an advanced stage of metamorphism, that they can hardly be distinguished in a microscopic slide from the fine edges of epidiorite sills. No traces of clastic structures are present, and the rocks consist chiefly of hornblende with a few garnets, some quartz and felspar, sometimes biotite, and accessories such as rutile and apatite.

It is noticeable that the garnets usually act as "eyes" in the epidiorite sills, the hornblende of the matrix curving round them, and often leaving triangular patches of quartz or felspar at either end. In the Green Beds, the garnets do not seem to have acted in this manner as a rule, the hornblende crystals abutting against or enclosing them. The foliation of these green beds also seems to be rather more regular than that of the edges of epidiorite sills.

In hand specimens several methods of distinction are possible: the epidiorites have the rusty weathered crust characteristic of igneous rocks; the fracture also resembles that of an igneous rock, and the lustre on a fresh cross fracture is greater than in the case of the Green Beds. In those specimens of Green Beds which most closely resemble the epidiorite sills, the fracture is more earthy, and the weathering and jointing are those of a schist of sedimentary origin; the lustre upon a fresh cross fracture is not so great, and the colour of the hornblende on a cross fracture is lighter, being more distinctly green as compared with the almost black colour of the hornblende in the epidiorites. These characteristics are, as a rule, sufficient to distinguish the edges of epidiorite sills from much altered hornblendic Green Beds, where field evidence is not available.

Specimens from other horizons have been selected and examined microscopically for the purpose of elucidating the progressive metamorphism, but space does not permit of any description of them being given here.

*District between Pitlochry and Blair Atholl.*—Mr. Craig thus summarises the results of his revision and re-survey of about fifteen square miles of the ground between Pitlochry and Blair Atholl in October, November, and part of December. It was

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anticipated that important evidence regarding the succession of strata would be obtained in this district, and special attention was accordingly given to evidence bearing in any way upon that question. Mr. Craig.

The area revised comprises the rocks from a horizon not far to the north of the Loch Tay limestone outcrop, a sill of epidiorite marking the boundary, and so north-westward, northward, and north-eastward to the first main outcrop of Blair Atholl limestone. Geographically, the various members of the series are arranged as follows, the section in the Tummel and Garry Rivers being taken as typical :—

(5) Blair Atholl Limestone.
(4) Black Schist.
(3) Quartzite.
(2) So-called Graphite Schist.
(1) So-called Calc Sericite Schist.

(1) The zone to which the name of calc-sericite schist has frequently been given, consists of felted mica schists and phyllites, often with quartz veinlets, but becoming more calcareous near the top, where thin limestones are observed, and calcareous sericitic beds, which have frequently developed bladed crystals of actinolite. These schists and limestone beds will be described in the explanation of Sheet 55 as the Beinn Lawers schists. A very easily recognised thin brownish limestone or dolomite forms the top of this group.

(2) This group consists of a dark leaden-coloured schist, to which the name Graphite Schist has frequently been given, because some of the upper beds are occasionally markedly graphitic. A thin black impure limestone has been mapped near the top of this group.

(3) The Quartzite has been spoken of as the Banffshire, Schiehallien or Central Highland Quartzite. The margin is fine, but a pebbly band is frequently seen a few feet within the mass.

(4) North of the quartzite comes an outcrop of dark leaden-coloured schist which is associated with a mass of (5) Blair Atholl limestone. Repetitions of the quartzite, dark leaden-coloured schist and limestone occupy the surface in the area to the northward. Details, most of which have come to light in the re-survey, are omitted in the above. Associated with limestone, a greater or less thickness of variable schists are sometimes observed, and Phyllitic schists, homotaxial with the black schist, appear in the northern part of the area.

That the series is an upward succession from the Loch Tay limestone to the most southerly outcrop of quartzite has been recognised for many years.

The evidence regarding the succession obtained during the re-survey can be considered conveniently under three heads: (*a*) Structural evidence, which can be considered irrespective of folding, dip, or pitch; (*b*) Petrological evidence; (*c*) Evidence from observation of pitch, and discordant junction of different members of the series.

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Mr. Craig.

(*a*) The first point of importance is the identification of the dark schist south of the main quartzite outcrop, with that north of the outcrop, *i.e.* (2) is the same as (4). On Meall Uaine, the so-called Graphite schist can be traced round the folds of the base of the quartzite into the black schist to the northward, associated with the Blair Atholl Limestone. There is no drift obscuring the ground, and the section is remarkably clear. The basal edge of the quartzite is seen folded with the under-lying schist, and usually much drawn out by shearing at the actual margin; but a few inches farther in, the quartzite is fairly solid.

Minor zones in the black schist can also be identified on both sides of the outcrop of quartzite. The thin dark limestone already alluded to is seen in several localities south of the quartzite outcrop, and near the summit of Meall Uaine it is found more highly altered, and beginning to develop Tremolite crystals. North of the quartzite it has the same appearance, but as we proceed north-eastward into a region of greater metamorphism, the Tremolite becomes more conspicuous and more highly crystalline, till the rock presents the appearance of the well-known Tremolite limestone, which has been so often recorded as a zone in the black schist, associated with the Blair Atholl limestone.

This identification of the black schist with the so-called Graphite schist, is further confirmed by the mapping of the Ben Lawers Schist, with its characteristic thin limestone band, round from south to north of the outcrop of the quartzite.

This evidence is sufficient to establish the fact that the quartzite is the highest member of the series, lies above the black schist, and when it comes in contact with the Blair Atholl limestone, as near the head of Allt a' Mhagain, must be above that deposit also.

All the rest of the evidence, while amply confirming this conclusion, bears more directly upon the relation of the quartzite to the other rocks in the district. The first point of importance is that no exposure of the Blair Atholl limestone has been observed south of the main outcrop of the quartzite. Again, the margin of the quartzite, and it follows from the evidence stated above that only one margin of the quartzite is seen in this district, comes in contact with the Blair Atholl limestone, variegated schists sometimes associated with the Blair Atholl limestone, the black schist, the Tremolite limestone in the black schist, and the Ben Lawers schist, with its thin band of limestone. It may also be mentioned here that the Quartzite comes in contact with a large laccolitic sill of foliated hornblende rock intruded between the Ben Lawers schist and the black schist, and also with a thin sill of garnetiferous hornblende schist intruded in the black schist. In the third place, the margin of the quartzite is seen to transgress the outcrops of other members of the series, as is indeed necessary in order for it to come in contact with all the above-mentioned groups. This transgression can be seen clearly in ground free from drift.

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From these facts it is possible to deduce two alternative explanations: (1) that most of the upper groups die out sporadically to enable the quartzite to apparently descend in the series, or (2) that there is presumptive evidence of an unconformable overlap of the quartzite upon the lower members of the series. Mr. Craig.

(*b*) Petrological evidence can be considered next, to see whether it confirms either of the above hypotheses.

A very striking fact came to light during the examination of the basal beds of the quartzite in different localities, *i.e.*, that these basal beds vary in character and composition according to the nature of the underlying rock. Coarse pebbly beds are not infrequent near the base of the quartzite, but the actual margins are almost invariably fine in grain, and appear to contain material derived from the adjacent rock. That this intermingling of material has not been caused by the disruption of bedding planes under shearing forces and the subsequent rearrangement of the affected material, is proved by the perfect continuity of the bedding planes, and the fact that the intermingling of material extends farther into the quartzite than any marginal belt of special shearing due to the sudden change in coefficient of elasticity in passing from a shale to a quartzite. The only possible explanation of the phenomenon is that contemporaneous erosion accompanied the deposition of the basal layers of the quartzite. The thickness of these bands in which evidence of this contemporaneous erosion can be obtained seldom exceeds two feet; they sometimes contain pebbles of quartz and felspar very little affected by shearing. The gradual passage of these bands into the purer quartzite is regular and well marked. Where the quartzite comes in contact with the black schist the basal laminæ of the former rock consist of rusty impure sandy micaceous schist containing muscovite, biotite, graphite (?) in some places, iron ores, and occasionally needles of tourmaline. These beds are usually soft and rusty, and are separated by films of sandy micaceous schist of a type differing completely from the normal black schist. This marginal type of the quartzite has been described in other areas as the Coire Neid type. When the quartzite comes in contact with the Tremolite limestone band in the black schist, the basal beds consist of impure calcareous quartzite, which is usually very rotten and friable, owing to the lime dissolving out under weathering processes and leaving the silica. There is not a sufficient area of contact between the quartzite and the Blair Atholl limestone in this district to make it possible to describe the general type of the marginal beds of the quartzite under these circumstances, but where the quartzite comes in contact with the variegated schists associated with the Blair Atholl limestone, and with the garnetiferous hornblende schist still in the black schist, the basal beds are represented by a very variable series of schists composed of quartz, felspar, muscovite, biotite, garnets, and occasionally hornblende or calcite, each constituent varying in quantity in different bands or different localities, but the whole, by becoming more quartzose, gradually passing into pure quartzite.

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Mr. Craig.

Throughout a great part of the area where there are no large outcrops of quartzite small infolds of the base of the quartzite are frequent. These infolds are sometimes very minute, but are invariably recognisable, and present the same phenomena of contemporaneous erosion and deposit.

Thus it has been seen that the base of the quartzite not only transgresses the boundaries between other members of the series but that its deposition was accompanied by local erosion in this area, and it follows that the quartzite is not conformable to the other members of the series. How great the unconformability may be it is impossible to say from the evidence in this district, but the absence of the Blair Atholl limestone from the area south of the first main outcrop of the quartzite is very significant; the limestone may either have never been deposited or it may have been entirely removed by denudation.

(*c*) Observations of the pitch of the folding confirm what is stated above with regard to the order of succession; Ben Lawers schist, black schist, Tremolite limestone, variegated schists, and Blair Atholl limestone are all seen to pitch below the quartzite.

The actual discordance between the bedding of quartzite and black schist can be seen in several places both south and north of the main quartzite outcrop, where the bases of folds of that rock are seen in contact with the black schist. Hand specimens can even be obtained showing this discordance, which may appear only as current bedding, but may mark a very considerable unconformity.

The succession, then, in this district, is proved to be as follows, in descending order:—

4. Quartzite.
3. Blair Atholl Limestone.
2. Black Schist, with Tremolite limestone near the top.
1. Ben Lawers Schists, with thin limestone at the top.

A gentle unconformability, which may be only local or may be of considerable magnitude, occurs at the base of 4, and occasionally cutting out 2 and 3 completely.

A point of great interest in the district is the development of pre-folding basic intrusions. Mr. Barrow pointed out several years ago that the source of at least one of the hornblende schist sills can be seen on Beinn Vrackie. It takes the form of a large flattened laccolite, spreading out into a thick sill, which thins out rapidly to the south and west, while to the north and east it extends farther. It is possible that there is more than one intrusion, but as the ground has not been entirely surveyed, it is impossible to be certain on this point. The main laccolite, which causes the strike of the strata to be deflected round it in a most regular manner, is intruded between the Ben Lawers schist and the black schist, approximately, but it also gives off a minor sill, which occupies a low horizon in the black schist. The igneous mass has been thrown into large rolling folds, while the surrounding rocks, of sedimentary origin, were compressed into

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a vertical isocline. The edges of the main sill, however, and the minor sill, have shared in the intense folding of the sedimentary series. Mr. Craig.

No detailed examination of the petrological characters of these intrusions has yet been made. It will be sufficient to state that the main intrusion, where it is least affected by movement, is a holocrystalline hornblende rock, very basic in composition, while the margins are represented by finely laminated hornblende schists, nearly always containing some garnets.

The sill in the black schist is invariably a very garnetiferous hornblende schist, the garnets sometimes attaining a diameter of an inch or more, while biotite is frequently present.

The main laccolite has caused considerable alteration of the hornfels type in the black schist, the latter rock being intensely indurated, so much so that, for a distance of from five to twenty yards from the junction, the hornfels has been able to resist, to a great extent, the shearing forces consequent upon the folding, so that it exists now as a compact hornfels.

It is in the relations of the quartzite to these basic intrusions that one of the most interesting problems of this district is found.

At Aldclune, throughout the Pass of Killiecrankie as far as a point just above the junction of the Garry and Tummel, and for several square miles to the east and north-east, the base of the Quartzite is continually coming in contact with the garnetiferous hornblende schist sill in the black schist. This sill is folded again and again with the base of the quartzite, but in no instance has it been seen to intrude in the quartzite. Following the lower edge of the latter, the sill is sometimes seen to be separated by a few feet of black schist from the arenaceous rock, sometimes a thickness of from a few inches up to six or eight feet of the sill is seen in actual contact with the base of the arenaceous group, while sometimes the sill appears to be absent altogether. Where the base of the quartzite descends in the series to the horizon of the Ben Lawers schist, no trace of this sill is seen.

Where this minor sill is in actual contact with the quartzite, a remarkable variation in the composition of the latter rock is noticed. The lowest layers for a thickness of from a few inches up to about three feet are not quartzite, but consist of highly quartzose rocks of variable composition containing biotite, some white mica, garnets, and very frequently hornblende. In these rocks the bedding is well marked, and on fresh fracture they present the appearance of banded, bluish, rusty-weathering quartzose schists, with the fracture and typical weathering of quartzite. In the Pass of Killiecrankie excellent waterworn sections of these marginal rocks are seen, biotite being the most abundant ferromagnesian mineral. Where hornblende occurs it is usually in bladed or feathery crystals lying at all angles to the bedding; garnet is always present in such cases, while biotite is less abundant, and white mica is more conspicuous.

The various bands differ in composition by the increase or decrease of one or more of the constituent minerals, but all varieties, by becoming gradually more quartzose to the exclusion

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Mr. Craig

of impurities, pass into the solid quartzite. Sometimes an almost pure quartzite with a few garnets is observed. The pebbles, which not infrequently characterise the lower beds of the quartzite, have occasionally been detected in these marginal beds, and in such cases they are very little affected by shearing stresses, showing that there has been very little differential movement during the folding.

Large rounded masses or short veinlets of quartz are sometimes observed at the junction with the sill, and even within the margin of the originally igneous rock.

These marginal beds may be repeated by folding, so that they cover a considerable area, but where a good section is examined they can always be proved to be only a few feet, or perhaps only a few inches, thick.

Where the Quartzite lies at a higher horizon than the sill, and the sill is enclosed by black schist on both sides, none of the above phenomena are noticed, either at the margin of the quartzite or at the margins of the sill.

From this evidence it seems probable that this sill has been intruded prior to the deposition of the quartzite, that the latter rests unconformably upon it in many localities, and that the basal layers of the arenaceous rock contain material derived from the denudation of the originally igneous rock.

Turning to the evidence from the large parent sill or laccolite, some confirmation of this view is found, but till the ground has been fully surveyed, it is impossible to speak conclusively.

It has been seen that the black schist has been hornfelsed by the intrusion, and that this alteration can still be detected. Now in several localities the base of the quartzite traverses the outcrop of the black schist and comes in contact with the hornblendic intrusion. In such cases no induration of the quartzite has been observed, but, on the contrary, the marginal beds present a rusty decomposed aspect, containing many impurities. In one and the same locality this rusty edge of the quartzite may be seen in contact with both the hornfelsed black schist and the coarse hornblendic sill.

In one or two localities also the base of the quartzite appears to traverse the outcrop of this sill or laccolite, and comes in contact with the underlying Ben Lawers schists.

The area examined is singularly free from faults of any magnitude and from igneous intrusions older than the folding.

The folding is never very deep, but is perfectly isoclinal. The area comprises part of the centre of the great fan structure of the southern Highlands; in consequence there has been none of the later shearing movements, and the grade of dynamic metamorphism is low, the shearing consequent on the folding being the only movement of the kind to which the rocks were subjected, with the exception of some strain slip cleavage developed in the finer and softer schists.

Where the thinnest edges of folds of the quartzite are enclosed in the black schist considerable evidence of shearing movement

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is observed, but within a few feet the quartzite becomes fairly massive, and pebbles are often very little drawn out. Mr. Craig.

In the area to the south of this district where the folding is flat or gently inclined, no traces of pebbles can be seen for a distance of from six to ten miles from this central axis.

The thermometamorphism is considerable, though nowhere intense; aluminous silicates have not been developed in the argillaceous rock, nor calc-silicates to any extent in the limestones, but all the rocks have been recrystallised.

*Strath Tummel District.*—The results of the re-examination of about 15 square miles of ground in the lower portion of Strath Tummel are thus given by Mr. Wilson. Mr. Wilson.

From south to north the various zones are found in the following geographical order—

(4) Limestone and black schist.
(3) Quartzite.
(2) Black schist with little black limestone.
(1) Ben Lawers schist.

(2) *Black schist with little black limestone.*—The greater portion of this group is a dark-blue schist. At some localities these dark bands alternate with grey schists with garnets, and occasionally the series becomes coal-black towards the top and contains graphite. The little black limestone is situated in this group.

(3) *Quartzite.*—This division varies from a solid white quartzite to pebbly quartzite and quartz-schist.

(4) *Limestone and black schist.*—The limestone is a blue to steel-grey holocrystalline rock, and the black schist is identical in every respect with the dark blue and black schists of group 2.

(1) *Ben Lawers schist.*—On the east side of the Frenich Burn there is a small area of these schists, which are entirely composed of large bladed crystals of actinolite in a sericitic base. The actinolite schist, along with the spotted brown limestone, forms a characteristic band at the top of the Ben Lawers schist. On the craggy ridges to the west of Pitlochry the upper and calcareous portion of this group contains two well-marked infolds of the black schist.

(2) *Black schist.*—To the west of the River Tummel at Pitlochry no alteration has been made on the previously traced outcrop of this group, but the occurrence within it of the little black limestone was proved at two different localities. From this southern outcrop, at a point one mile west of Farragon, the black schist has been traced continuously across the watershed into Strath Tummel, where it stretches from near the head of the loch to a distance of two miles below its outlet. All through Strath Tummel the different members of this zone are constantly repeated by the shallow isoclinal folds. As the result of this folding the boundary lines are much involved. The small black limestone and black tremolite rock has been observed at several localities within the area to the south of Loch Tummel.

On the north side of the river and loch this same zone of black schists has been continuously traced from the foot of Glen

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Mr. Wilson. Fincastle to a point north of Portnellan House, where it is truncated by the Loch Tay fault. This area of black schist is only separated from the outcrop of the Blair Atholl limestone and its black schist on the watershed between the Rivers Tummel and Garry, near Lochan na' Leathain, by a narrow belt of ground obscured by superficial deposits 300 yards wide, and there is a strong presumption that the black schist is continuous across.

To the north-east of the large Strath Tummel belt, and separated from it by quartzite, another area with a very irregular boundary stretches from near Fincastle House to the River Garry, and is continuous with the black schist mapped by Mr. Cunningham-Craig on the east side of this river, and several small inliers occur within the quartzite at the foot of the Tummel Valley.

(4) *Limestone.*—Within the area of the black schist already described as extending west to the Loch Tay fault, and about a quarter of a mile east of Loch Tummel Inn, the cliff called Creag Mhor is formed of a mass of steel-grey limestone, identical in character with the Blair Atholl limestone as developed a little to the north-east at the head of Glen Fincastle, and there can be little doubt that it is a western extension of that seam. In this exposure the limestone is visible in three separate folds surrounded by and folded with the black schist. In the immediate vicinity of Creag Mhor there are two other separate outcrops of a similar limestone associated with the same belt of black schist.

At the head of Glen Fincastle near Edintian and the black schists, there is a considerable outcrop of black limestone, which has been recognised by Mr. Wilson as the "little black limestone." He regards it as the same limestone which occurs in the southern outcrop, and from this correlation as a necessary consequence, the identity of the black schist in the two areas follows. The triangular area on the south side of the River Garry is occupied by Blair Atholl limestone and black schist, and there can be no doubt we are dealing with the same black schist and limestone as at Creag Mhor, because at the head of Glen Fincastle, the little black limestone and black schist both dip under the Blair Atholl limestone.

*Quartzite.*—The character of this rock varies considerably over this area. To the S.E. of the junction of the Tummel and Garry on both sides of Loch Tummel, and at several other localities, the black schist is immediately overlaid by a solid white quartzite containing felspar. In the direction of Farragon, this massive type gives place to a grey quartzite with strong pebbly bands, either at the edge or else some little distance from it. The grey colour is due to small lenticular fragments of black schist which are enclosed in the quartzite matrix. This fact seems to indicate that local denudation of the black schist was taking place at some point or points in this district, during the period of deposition of the quartzite.

At several points in Strath Tummel, the edge of the quartzite next to the black schist is slightly calcareous, and generally occurs as a weathered crumbling gritty rock. The

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pebbly edge of the quartzite is found as far as Loch Tummel, and on both sides of the belt of black schist which extends northwards from Farragon. From Glen Fincastle to the Pass of Killiecrankie, the quartzite is very much folded and inter-felted with bands of black schist. Here the edge rock of the quartzite is essentially a quartzose schist with a rusty brown weathering, and frequently contains biotite, tourmaline, and other minerals. Mr. Wilson.

*Basic intrusions.*—Throughout the pass of Killiecrankie, a much folded epidiorite sill with garnets (sometimes 1 inch in diameter) is associated with the black schist. This sill occurs at many points to the west, and as far up Strath Tummel as the foot of the loch. It is sometimes intrusive in the black schist, but is more frequently in close contact with the quartzite on the one side, and the black schist on the other.

*Relation of the Quartzite to the other Zones.*—The occurrence of black schist fragments in the pebbly quartzite has already been mentioned as evidence in favour of the view that local erosion of the black schists took place in the present region during the deposition of the quartzite. At Creag Mhor the quartzite is seen to transgress from the Blair Atholl limestone on to the black schists. To the north of this point, the same edge of the quartzite is successively in contact with the Blair Atholl limestone and with the black schist for a short distance. Over the portion of the area (already described) occupied by the pebbly edge of the quartzite, the latter occurs next to the black schist, but at the Frenich Burn, this pebbly edge for some distance is in contact with the "Ben Lawers schist," exposed in the small area already noticed.

Within the triangular space on the south side of the River Garry occupied by black schist and Blair Atholl limestone there is a considerable area of solid white quartzite, the outer edge of which rests on black schist and the inner edge on limestone. This same belt of limestone passes outside the quartzite and is then on both sides in contact with black schist.

These facts afford strong presumptive evidence in favour of an unconformability between the quartzite and the other members of the Highland schists in this area.

## II. PALÆONTOLOGICAL WORK.

Mr. Peach, the Acting Palæontologist, has prepared the following summary of palæontological work in Scotland during the past year. Mr. Peach.

The Palæontological department in Scotland was carried on during the season by Mr. Peach, assisted by Dr. C. B. Crampton, Mr. A. Macconochie, and Mr. D. Tait. Assistance had also been afforded by the following specialists outside of the Geological Survey, viz., Dr. Traquair, Dr. Wheelton Hind, and Mr. R. Kidston.

The number of fossils gathered by the Fossil Collectors during the year is 1191, of which 31 are from the Ludlow and 74 from the Downtonian rocks of Lanarkshire, 20 from the Lower Old



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Mr. Peach. Red Sandstone of Fife and Dumbarton, 298 from the Carboniferous rocks of Berwickshire, Fife and Arran, 719 from the Secondary rocks of the Isle of Skye, and 50 from the Post-Tertiary Clays of Loch Lomond. During the season the fossil collectors were much engaged in collecting rock specimens, which they gathered to the number of 2,693. In view of the publication of the memoir on East Fife Sir Archibald Geikie desired that collections of fossils should be made from certain shaly beds of the Lower Old Red Sandstone that emerge from beneath the great volcanic platform of the Ochils and are exposed on the shore of Wormit Bay on the south of the Firth of Tay nearly opposite Dundee, and also from Parkhill in the same neighbourhood whence Professor Fleming obtained the first described specimens of *Parka decipiens*. Collections were accordingly made by Mr. Macconochie. The fishes, determined by Dr. Traquair, are *Mesacanthus Mitchelli*, *Ischnacanthus gracilis*, and *Climatius scutiger*; the other forms, determined by Mr. Peach, are *Pterygotus anglicus*, *Eurypterus sp.*, and *Parka decipiens*. The assemblage of fossils is like that found at Duntrune and Balruddery on the opposite side of the Firth.

For the same purpose it was found to be highly desirable that certain plant bearing beds in the Lower Carboniferous rocks exposed on the shores of East Fife should be specially searched for plants. Mr. Kidston, accompanied by Mr. D. Tait, devoted a few days to this investigation, with the result that they obtained a considerable amount of material. The results of Mr. Kidston's study of the plants obtained will be incorporated in the forthcoming memoir. One of the plants, *Sphenopteris foliolata*, Stur, obtained by them is new to Britain.

At the instance of Mr. Gunn, and for the purpose of obtaining additional information for the forthcoming memoir on the Geology of part of Arran, Mr. Tait made a collection of fossils from the shingle beach on the north side of Catacol Bay, in Arran, as Mr. Gunn thinks that there is strong presumptive evidence that Carboniferous Limestone rocks occur in the sea just outside of Catacol. Mr. Peach determined the fossils, which appear to denote the horizon of the Upper Limestone group of the Carboniferous Limestone series of Scotland.

In order to follow up the discoveries made in the Ludlow and Downtonian rocks of Lanarkshire, Mr. Tait in the early part of the season made a considerable collection from these rocks in the Lesmahagow inlier in Lanarkshire. The fishes have been determined by Dr. Traquair, but no new points of morphological interest have been exhibited by the specimens. Several good specimens of *Pterygotus* and *Slimonia* were obtained by Mr. Tait from the site of the Logan Water Reservoir at present in course of construction.

In the autumn Mr. Kidston once more placed his valued services at the disposal of the Geological Survey, and, accompanied by Mr. Macconochie, made a search for rare fossil plants among the lowest Carboniferous rocks of the Border. The results are embodied in the accompanying report by Mr. Kidston,

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Mr. Peach. While searching for plants they also obtained a valuable collection of fossil crustacea. They also made a very interesting discovery of pseudomorphs after crystals of salt in some shales of the Cementstone group of the Lower Carboniferous "Tuedian Beds" exposed in a scaur of the Blackadder Water near Allanton, in Berwickshire. The particular interest attaching to the find is the additional evidence this affords in favour of the view of the Cementstone phase of the Lower Carboniferous rocks being deposited in concentrated saline waters.

The following is Mr. Kidston's Report on fossil plants gathered from the Calciferous Sandstones of the Berwickshire border:—

Mr. Kidston. "From the great interest of the specimens collected last year in Berwickshire (see Report for 1900, p. 174), a second visit was made towards the end of last season with the object of further investigating the fossil flora of the Calciferous Sandstone Series. The results were very satisfactory, and again led to the discovery of some new and interesting species.

"Specimens were collected from the following localities:—

"From the Whiteadder Water, right bank, scaur under Edrom Church. (This locality is described in first notes, p. 174, as 'Right bank of Whiteadder, one-fourth mile west of Edrom House,' but the above designation is more definite.)

"To those recorded from this locality last year the following must be added:—

*Sphenopteris elegans*, Brongt.
This is the *Sphenopteris* sp. of first list.
*Lepidodendron Veltheimianum*, Sternb.
This is probably the *Lepidodendron* sp. of first list.
*Stigmaria ficoides*, Sternb. sp.
*Cardiocarpus bicaudatus*, Kidston.

"From right bank of Whiteadder Water at Willie's Hole, one mile east of Allanton. (In previous notes designated as from 'Right bank of Whiteadder, three-quarters-of-a-mile below Allanton'):—

*Marchantites* sp. Distinct from that already noted.
*Lepidodendron Veltheimianum*, Sternb.
*Stigmaria ficoides*, Sternb. sp., *var. undulata*, Göpp.

"From Road Cutting, north end of Norham Bridge over Tweed, a Nœggerathia-like pinnule was found in the upper portion of a cement stone band about twelve inches thick, in the shales a few feet above the level of the road.

"Some material showing plant structures was also collected, but this has not yet been examined.

"From small stream, about a quarter-of-a-mile N.E. of Ladykirk:—

*Asterocalamites scrobiculatus*, Sch. sp.



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Mr. Kidston. "From Blackadder Water, right bank, about a quarter mile above Allanton Bridge:—

*Lepidodendron spetsbergense*, Nath.

"From Whiteadder Water, Bellsburn Scaur, near Chirnside:—

*Aneimites* sp.

"From Langton Burn, about four hundred yards N.N.E. of Gavinton, near Duns:—

*Lepidodendron spetsbergense*, Nath.

"Marshall Meadows Bay, two-and-a-half miles north of Berwick.

"These beds are above the Scremerston Coals, and below the position of the Hurlet Limestone:—

*Sphenopteris (Diploehmema) Schutzei*, Stur.
*Cardiopteris polymorpha var. rotundifolia*, Göpp. sp.
*Asterocalamites scrobiculatus*, Schl. sp.
*Pinnularia*.
*Lepidodendron Veltheimianum*, Sternb.
*Lepidostrobus*.
*Stigmaria ficoides*, Sternb sp.

"The specimens of *Asterocalamites scrobiculatus* were very fine, some being about a yard long. The *Stigmaria* showed the attached rootlets very beautifully, the rhizomes not being crowded, the rootlets were seen to extend from them at right angles, and about a foot long where they were broken over. Several rootlets were found which ended in a bifurcation.

"In addition to the two localities mentioned in the Report for 1900, viz., Langton Burn Road Cutting, north end of Norham Bridge, from both of which additional material was collected, some small blocks of a shelly limestone were found in the shingle on the Whiteadder Water immediately below the right bank scaur under Edrom Church.

"The plant remains in these are not so well preserved as those in the Langton Burn material, but the blocks contain much the same species. The Edrom material has, however, yielded a *Heterangium*, a genus not previously met with in Berwickshire.

"Microscopic preparations are at present being made from these materials showing plant structure, and already about one hundred and fifty slides have been prepared; but still a considerable amount of material awaits examination, so a Report on these specimens will be deferred for a future occasion. It may be mentioned, however, that the plants are of very great interest, and have added much to our knowledge of palæozoic botany."

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Mr. Peach. A large collection of fossils was made by Mr. Tait from the Secondary rocks of the Isle of Skye during the season, to assist the Surveyors in fixing the horizons of these rocks as developed in Sheet 71 (one inch). They include fossils from each of the sub-divisions from the Infra-Lias or local representative of the Rhaetics up to the Oxford Clay. These fossils have all been sent to Mr. E. T. Newton for determination and classification. A few specimens of fossil wood showing structure collected from beds which may be of Triassic age have been submitted to A. C. Seward for examination. During the season a most interesting and important discovery was made by Mr. Clough who, as already stated in a former part of this report (p. 146), found cherty rocks in beds underlying the great Tertiary volcanic plateau in Skye, on the north side of Soay Sound in Sheet 70 (one inch). According to Mr. E. T. Newton, to whom the specimens were submitted, the cherts contain fossils which appear to belong to the Greensand division of the Cretaceous, an opinion also shared by Dr. G. J. Hinde (see p. 92).

Mr. Cunningham Craig, who surveyed the islands in Loch Lomond, wished a further collection of shells to be made from the Glacial Clays of Inchlonaig, which he considers to be of the age of the Hundred-feet Beach. Mr. Macconochie was, therefore, detailed to make the collection, which has been submitted to Mr. E. T. Newton, and a list of about 20 species has been supplied to Mr. Cunningham Craig for insertion in the forthcoming memoir of Sheet 38 (one inch).

Mr. Macconochie obtained from the Calciferous Sandstones on the banks of the Whiteadder, near Dunse, specimens of a fish spine in addition to one he had collected from the same locality many years before. The spines are considered by Dr. Traquair of sufficient interest to warrant the construction of a new species of *Gyracanthus*, the description of which by him is here given:—

Dr. Traquair. "*Gyracanthus falciformis* n. sp. Traquair.—Length, four and a half to six inches; very decidedly and evenly curved antero-posteriorly from base to apex; stout at the base and rapidly tapering to the point. Inserted portion short, exposed part covered with closely set oblique ridges which get more and more oblique, till towards the point they are nearly parallel with the posterior margin of the spine; ridges tuberculated near the base, but tending to become quite smooth towards the apex. Posterior area narrow; unsymmetrical as usual; each of its margins being set with a row of very small oblique denticles.

"The well marked configuration of these comparatively small spines (of which there are three pretty entire specimens in the Survey collection) prevents me from considering them to be the immature form of any known species."

Mr. Peach. Lists of fossils were drawn up by Mr. C. B. Crampton and Mr. D. Tait, under the supervision of Mr. B. N. Peach, for the Appendix of the East of Fife Memoir.

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Mr. Peach. The following is a list of Specimens in the Survey collection figured in the Palæontographical Society's volume for 1901 :—

A Monograph of the British Carboniferous Lamellibranchiata by WHEELTON HIND. Vol. ii, part 1.

*Pteronites angustatus* from Lower Carb. Series, Lawston Linns, Liddle Water. Plate v., fig. 1.

*Pteronites angustatus* from Calc. Sa. Series of Glencartholm, Dumfriesshire. Plate v., fig. 4.

*Actinopteria fluctuosa* from Clecklimon, Kilbride. Plate v., fig 8.

„ „ from the first limestone on the shore E. of Kinghorn. Plate v., fig. 2.

*Actinopteria fluctuosa* from W. Quarry at Salton. Plate v., fig 12.

*Posidonomya corrugata* from near Paisley. Plate vi., fig. 3.

„ *radiata* from Calcif. Sa. Glencartholm, Dumfriesshire. Plate vii., fig. 7.

A Monograph of British Graptolites by G. L. ELLES and E. M. R. WOOD, edited by C. Lapworth. Part 1. Dichograptidæ.

*Didymograptus serratulus* from Minnoch Water, Glencaird Lodge, S. Scotland. Glenkiln Shales. Plate ii., fig. 7.

The Ganoid Fishes of the British Carboniferous Formations by R. H. TRAQUAIR. Part 1. Palæoniscidæ.

*Elonichthys pulcherrimus* (scales only). Plate xii., fig. 2.

„ *serratus* (scales only). Plate xii., fig. 6.

## III. MUSEUM WORK.

Mr. Goodchild. The Curator of the Geological Survey Collections in the Edinburgh Museum of Science and Art, reports that during the year now at a close, the principal work done in the Geological Survey Gallery has been the re-arrangement of a large part of the collection of rock specimens, and the intercalation amongst these of new specimens of interest collected by the Survey officers, or given by others. A large number of the specimens of fossils have been retableted, and the descriptions written anew. In the course of this work the figured specimens have received special attention. A number of specimens of fossils from the Clyde Beds have been mounted and placed on exhibition. In addition to this, the important work of arranging the part of the collection which is not exhibited has been carried on. These specimens are arranged primarily under their respective biological headings, and secondarily under the number of the Ordnance Survey one-inch Sheets, so as to be available for immediate reference for lists. The collection of rock specimens placed in the glazed cases beneath the maps, has been catalogued with the special object of facilitating reference to such of the specimens as may be duplicates.

During the year the third edition of the Guide to the Geological Survey Collections was sold out, and a new edition was forthwith prepared and placed in the hands of the Director of the Museum for publication as before.

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## IV. MAPS, ETC., PUBLISHED.

Two sheets of the one-inch map have been published during the year, viz :—

No. 21, the northern part of Arran, part of Bute and the Cumbraes.
No. 38, embracing the districts of Loch Lomond, Loch Katrine and Callander.

### *Extra Official Publications,* 1901.

BARROW, G.—"On the occurrence of Silurian (?) Rocks in Forfarshire and Kincardineshire, along the Eastern Border of the Highlands." *Quart. Journ. Geol. Soc.*, vol. lvii., p. 328.

GUNN, W.—"On the Old Volcanic Rocks of the Island of Arran." *Trans. Geol. Soc. Glasgow*, vol. xi., p. 174.

———"On Recent Discoveries in Arran Geology" (read at British Association meeting, Glasgow). *Geol. Mag.*, Sec. IV., vol. viii., p. 565.

HARKER, A.—"Ice Erosion in the Cuillin Hills, Skye." With map. *Trans. Roy. Soc. Edin.*, Vol. xl., part II., pp. 221–252.

———"The Sequence of the Tertiary Igneous Rocks of Skye." *Geol. Mag.*, (4), vol. viii., pp. 506–509.

HILL, J. B.—"On the Crush-Conglomerates of Argyllshire." *Quart Journ. Geol. Soc.*, vol. lvii., pp. 313–327.

KYNASTON, H.—"On some tuffs associated with the andesites of Lorne.' *Trans. Edin. Geol. Soc.*, Vol. viii., pp .87–90.

PEACH, B. N.; W. GUNN, and E. T. NEWTON.—"On a remarkable Volcanic Vent of Tertiary Age in the Island of Arran, enclosing Mesozoic Fossiliferous Rocks." *Quart. Journ. Geol. Soc.*. vol. lvii., p. 226.

# III.—IRELAND.

## I.—FIELD WORK.

### DUBLIN DISTRICT.

Mr. G. W. Lamplugh, District Geologist.
Mr. J. R. Kilroe,
Mr. A. McHenry,
Mr. H. J. Seymour,
Mr. W. B. Wright, } Geologists.

Mr. Lamplugh and Staff.

The mapping of the drifts on the six-inch scale in the neighbourhood of Dublin was commenced in May, and the area represented on the one-inch Sheet 112, with so much of the margin of the adjacent sheets as lay within the slips of the six-inch maps required to complete that sheet, was completed by the end of November, the total area surveyed being 156 square miles. Attention was devoted exclusively to the drifts and other superficial deposits, though in traversing the ground a few facts were

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Mr. Lamplugh and Staff.

noted in regard to the solid rocks which will be useful in preparing the new edition of the Memoir on Sheet 112, this memoir being at present out of print.

The MSS. six-inch maps of the former "solid" survey were examined, and a few notes relating to the drifts were transferred from them to the new working six-inch field-maps, but it was found that these notes were too scanty and the sketch-boundaries originally drawn for the drifts too diagrammatic to yield any material aid in the preparation of the drift-map. It has therefore been found necessary to make a thorough re-examination of the ground so far as the superficial deposits were concerned, but this has occupied much less time than would have been required if the re-examination of the solid rocks also had been undertaken. Notes were made on the field-maps as to the present state of the land, whether under grass, tillage, etc., and also as to the character of the soil, so far as this could be determined by traverse only.

It was observed that in this district, as in most parts of the United Kingdom, the area under tillage has evidently decreased greatly of late years, while the area of grazing land has correspondingly increased, and is largely occupied by dairy farms, from which a large proportion of the milk-supply of Dublin is drawn.

The greater part of the area in Sheet 112 is an undulating plain of Lower Carboniferous rocks more or less deeply drift-covered, but the southern side includes the northern margin of the Leinster Granite, with strips of the Older Palæozoic rocks fringing the granite on the east and on the west, and in this district the ground becomes mountainous and the drifts more irregularly dispersed. The plain is trenched by the valleys of the Tolka, Liffey and Dodder Rivers discharging into Dublin Bay, while the easterly part of the hilly tract is drained by small streams falling into Killiney Bay. On the north side of Dublin Bay the rugged peninsula of Howth with its attendant islet of Ireland's Eye, composed of the Older Palæozoic rocks, lies within the sheet. The shape of the ground has profoundly influenced the characters and mode of occurrence of the glacial deposits, so that the study of the physiography and of the glacial geology of the district are closely interlinked.

The area surveyed was divided out among the members of the field-staff as follows:—Mr. Kilroe mapped the district extending from the south-west suburbs of Dublin to the southern margin of the sheet, including the coast-line from Merrion through Kingstown to the south side of Killiney Bay (six-inch Sheets 23 and 26), and also an inland tract on the lower slopes of the Dublin Mountains extending westward to Rathfarnham (eastern half of Sheet 22). Mr. McHenry examined the central district (six-inch Sheet 18), including the City of Dublin and its suburbs northward to the Tolka Valley and westward along the Liffey Valley to Chapelizod, with the ground to the southward (western half of Sheet 22) up to the foot of the hills, and westward north of Tallaght to the margin of the map (north-east corner of Sheet 21). Mr. Seymour and Mr. Wright divided between them the northern and western margin of the map from Howth westward

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beyond Blanchardstown (S. part of six-inch Sheets 13, 14, and 15, with Sheet 16), and thence southward to Clondalkin (E. part of Sheet 17); these officers likewise surveyed the mountainous ground on the south between Glenasmole and Stepaside (north part of six-inch Sheet 25). Mr. Lamplugh mapped a small tract in the extreme south-west corner of the sheet (parts of six-inch Sheets 21 and 24), and also undertook general charge of the field-work, instructing and advising the officers in respect to the mapping, and inspecting the work when done. Mr. Lamplugh, and Staff.

The previous literature relating to the drifts of this district is extensive, the fine coast sections and the high-level shelly gravels of the mountain slopes having received especial attention. In the forthcoming memoir full reference will be made to this literature, and meanwhile it will suffice to mention that among the chief contributors to the subject have been the Rev. Maxwell H. Close, J. Kelly, the Rev. Canon Grainger, G. H. Kinahan, Prof. E. Hull, A. Bell, T. Mellard Reade, Prof. W. J. Sollas, and R. Lloyd Praeger.

In order to make clear certain detailed results to be afterwards recorded, which were obtained severally by the above-mentioned officers, it will be advisable to give first a brief outline of the broader features of the drift deposits of the neighbourhood of Dublin.

From the northern margin of the map up to the foot of the mountains, the prevailing material is a tough dark boulder-clay, highly calcareous, both in the matrix and in the included stones. This boulder-clay represents the crushed material of Carboniferous Limestone and its accompanying shales, but it usually contains also a few fragments of Silurian grit, Old Red Sandstone, and various intrusive rocks transported from beyond the limits of the limestone. Though moulded upon or against the bolder rock-features, it fills up and obliterates all the minor inequalities of the rock-surface, forming smooth gentle slopes descending gradually toward the main drainage hollows of the inland districts and eastward toward the sea. It appears at one time to have obliterated all the minor stream-courses of the district, and also the sharper features of the principal river-valleys, the present streams having in most cases re-excavated channels through the boulder-clay which sometimes coincide with their former rock-channels and sometimes do not. The smooth featureless surface of the boulder-clay usually gives no indication as to the thickness of the drift, the solid rock being in some places within a foot or two of the surface, while in other places it may be buried to a depth of 100 feet or more; it is usually found, however, that the deposit is thickest at the lower level, and thins away toward the crests of the smooth rounded swells which form the minor watersheds of the Carboniferous plain, so that on these crests the rock is often only thinly sprinkled with drift. The limestone also crops out in a few curiously bold bosses along the northern margin of the map,

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Mr. Lamplugh and Staff.

where massive pale crystalline limestone having the much discussed "knoll-structure" occurs among the thinly-bedded shaly Calp Limestone. Glacial striæ were observed in numerous places beneath this boulder-clay, and these indicate a general movement of the glaciating agent from about N.N.W. to S.S.E. over the plain, *i.e.*, from the interior toward the sea. As will presently appear, however, this direction changes on the eastern flank of the mountains; and both to the northward and southward of the present map the striæ indicate an ice-flow roughly parallel to the present coast-line.

The homogenous character of the boulder-clay is lost as we leave the limestone plain and enter the granite country, owing, in the western part of the district, to the admixture of granitic and other local detritus (which curiously hugs the slope of the hills and never extends beyond a very short distance on the plain), and in the eastern part to the incoming of a boulder-clay of different composition which appears partly to replace and partly to underlie the limestone-clay.

Mr. Lamplugh.

Disconnected patches of stratified drift-material make their appearance here and there over every part of the drift-plain, and evidently represent the local sifting of the ice-borne detritus by flowing water. This local sifting has taken place during the accumulation of some of the boulder-clay as well as in later times. In the former case the assorted material has probably been derived directly from the melting ice, and in the latter from the washing down of the previously deposited clay. It has, therefore, been found possible in most cases to make a rough classification of the gravels according to age, though in places where gravels of different age are conterminous their separation was scarcely practicable.

On the drift-plain north of the Liffey the stratified material occurs chiefly in elliptical mounds or short ridges, sometimes arranged in clusters and sometimes rudely lineated, and often associated with outcrops of the solid rock-floor. Owing to the clayey character of the residual soil formed from the decay of the more or less argillaceous limestone-pebbles which preponderate in the gravels, there is frequently little or no surface indication that these mounds differ in composition from the surrounding boulder-clay tract; but so many open sections of gravel and calcareous sand were observed in them that there can be little doubt these mound-features, where not caused by bosses of solid rock, are nearly always due to the presence of a core of stratified drift, and that in this district there are few or no true "drumlins" of boulder-clay. These mound-gravels may rest either on boulder-clay, or on the solid rock. In three or four instances where sections were exposed, their lower flanks were seen to be enwrapped and covered by the higher portion of the boulder-clay, with a more or less gradual passage downward and inward from the unstratified into the stratified drift. The bedding of the mounds is generally arched in the same direction, though not so steeply as the surface. They present, in short, all the usual

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"kame-structures," and must be closely associated in age and mode of origin with the continuous esker-ridge south of the Liffey, next to be noticed. Mr. Lamplugh.

The most northerly indications of this esker, in the country examined, appear to be the irregular gravel mounds and ridges seen on both sides of the Liffey Valley near Chapelizod, but the continuous embankment-like ridge sets in at Drimnagh, about a mile further south, and runs southward thence with a sinuous course for nearly three miles, to the Dodder Valley, while its prolongation south of that river is again indicated by broken mounds ground, trending now to the eastward. The characteristic esker-structure is beautifully displayed in the numerous large gravel-pits opened into this ridge. Though usually resting on boulder-clay this esker crosses a low ridge of limestone about mid-way in its course, and the fortunate occurrence of a deep pit at this point reveals new evidence of much interest. It is here seen that the gravel in the middle of the ridge rests upon a battered and water-worn floor of limestone, but that a few yards outward, towards the western side of the esker, the bottom gravel passes into gravelly clay full of scratched stones, resting upon a well-scratched rock-surface.

Here, then, is definite proof that at this point the waters carrying the gravel were at ground-level, and also apparently that they were hemmed in by ice at the margin of the ridge.

In approaching the mountains the drifts show a rapid increase in stratified material, and at the highest levels they usually end off upon the hills of granite and slate in thick irregular masses of sand and gravel, composed of the materials of the limestone-drift mingled with local detritus and with a few far-travelled stones. The presence of shell-fragments in this portion of the drift, at elevations up to 1,200 feet, has been the subject of much discussion, and is usually held to imply a submergence of the land to this extent; but the position, mode of arrangement, and contents of shell-bearing drifts, as well as the general tenour of the physiographical evidence, is quite incompatible with the view that they represent marine deposits; while on the other hand the facts all converge to prove that we are dealing with the marginal phenomena of an ice-sheet.

Excellent sections exhibiting the relationship between the high-level and low-level drifts are exposed in the high river-banks of the Dodder in Glenasmole, and in the glens of the mountain streams which join the Dodder at Rathfarnham. At the edge of the plain these usually show the intercalation of gravel, sand and silt between two boulder-clays, and the rapid thickening of the stratified material, at the expense especially of the upper boulder-clay in passing up the valleys, until finally the upper clay disappears entirely. The gravels then occupy the surface in a mounds belt, overlapping the lower clay and ending off on the slopes or in the high cols of the solid rock. Similar phenomena on a smaller scale are seen on the northern side of the rocky promontory of Howth, where a thick shell-bearing sand and gravel, banked against a rock-slope

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Mr. Lamplugh.

opposite the mouth of a wide hollow, is seen to fade out laterally between two boulder-clays. Where dominated by steep rock-slopes, the drifts are usually overspread and more or less intermixed with local rubble, which appears to have been washed down the hillsides by rain and floods both during and after the formation of the upper part of the drifts.

Besides the gravels associated, as above described, with the boulder-clay, there are, in several parts of the district, tracts of gravel of later age, but still of considerable antiquity. These gravels overspread the drifts in flat sheets occupying comparatively low and depressed ground, but yet usually outside the confines of the present river valleys. They are clearly associated with the rapid denudation which took place when the land was once more laid bare, but before the streams had re-excavated proper channels and were comparatively unconfined. The largest tract of this kind in the present map lies immediately to the south of Rathfarnham, and represents the gravels suddenly thrown down by the flooded mountain-streams on reaching the foot of the slope. From the gravels of this character to the high-level river gravels there is often but a step, and the latter descend by successively lower terraces to the recent alluvium, as is excellently seen in the valleys of the Dodder and the Liffey. Thus, from the period of deposition of the high-level drifts to the present time, there is clear proof of uninterrupted land conditions, except in a narrow strip along the coast-line where an ancient sea-beach, raised a few feet above present high-tide level, is distinctly marked.

A striking but hitherto neglected peculiarity of the district around the foot of the mountains, is the presence of numerous short, deep, water-cut gorges with precipitous walls, notching across projecting spurs of the granite and slate rocks in positions where, under existing circumstances, no stream could flow. These are now either quite dry or occupied only by a mere trickle of the rainfall-water collected within them. There seems to be no other possible explanation for these gorges than that they were excavated by powerful streams either draining directly across the ice-sheet or representing the overflow from the small lakes held in between the hills on the one side, and the margin of the ice-sheet on the other, after the manner made familiar by the recent geological explorations in Greenland and Spitzbergen.

In the S.W. corner of the map, notches of this kind are conspicuous on the slopes of Slievenabawnoge; on the opposite side of Glenasmole a very fine example, with walls 90-100 feet high, cuts the ridge south of Montpelier House at an elevation of 1,035 feet; others occur on the lower spurs of Three Rock Mountain; and a small but typical example at a lower elevation gashes the low ridge of granite one mile south of Carrickmines.

Advantage may be taken of this opportunity to state, with little hesitation, that the picturesque and much-visited gorges of The Scalp and The Glen of the Downs, lying respectively one mile and seven miles to the southward of the margin of the district at present under examination, may be assigned to the

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same agency, and that these exhibit the characteristic features of "overflow channels" on the grandest scale. Mr. Lamplugh.

The study of the present river-valleys of the district has yielded some instructive results in regard to its post-glacial denudation. The pre-glacial valleys of the Liffey and the Dodder, within Sheet 112, appear to have coincided in most places with the present valleys, so that these streams have been mainly occupied since glacial times in clearing out the drift-material with which they were choked. Here and there, however, they have swerved from the original channels in the process; as, for example, at Palmerston where the Liffey at its sharp elbow has cut a deep ravine in the Carboniferous Limestone, while there are indications that its drift-filled pre-glacial channel lies a little to the northward of the present river. The southerly tributaries of the Dodder appear also for the most part to be following their old courses; with an occasional striking divergence, as where the little stream from Piperstown swings away from its drift-filled depression and plunges through a deep chasm across the spur of slate to join the Dodder near Fort Bridge. But in the irregular ground between the southern shore of Dublin Bay and the mountains, the old drainage system is much confused, and the streams have carved new channels for themselves in the granite in many places. North of the Liffey also, the Tolka, for the greater part of its course in Sheet 112, occupies a new channel, cut through the drift into the limestone, and no definite evidence is yet forthcoming as to its pre-glacial course.

The general conclusion to be drawn from the post-glacial work of the streams is that a comparatively long period must have passed since the recession of the ice from the district.

The more important of the local observations of the several members of the Irish staff, with some individual conclusions which have not found place in the preceding *Summary* will now be given.

In the south-western corner of the district, just beyond the margin of Sheet 112, Mr. Lamplugh found that the projecting spur of the mountains lying west of Glenasmole, composed of the slate with igneous intrusions, was in part capped, to a depth exceeding 12 feet in one section, by stiff calcareous till containing many striated boulders of Carboniferous Limestone. This boulder-clay reaches an elevation of over 1,100 feet above O.D., although the steep sides of the spur are free from drift. This is the greatest altitude to which the limestone boulder-clay, as distinguished from the stratified drift, has yet been traced. As the high-level drift usually consists of gravel, sand and local rock-rubble, which many observers hesitate to recognise as glacier-borne, the presence at this altitude of typical boulder-clay which would be generally acknowledged as the direct product of land-ice, is of importance in proving that the ice-sheet must have been sufficiently thick to reach the level of the highest gravels.

In the south-eastern part of the sheet the tract of 32·2 square miles, surveyed by Mr. Kilroe, is mainly underlain by granite, Mr. Kilroe.

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Mr. Kilroe. over which the drifts are somewhat irregularly distributed. The following useful table compiled by this officer will serve to show the relative area of the various superficial deposits and of the solid rock :—

| | Total area. | Rock. | Local Drift. | Limestone Boulder-clay. | Glacial Sand and Gravel. | Late Glacial Flood-gravel. | Old River Alluvium. | Recent Alluvium. | Intake. |
|---|---|---|---|---|---|---|---|---|---|
| In Six-inch | Acres. | Acres. | Acres. | Acres. | Acres. | Acres. | Acres. | Acres. | Acres. |
| Sheet 22 | 7,686 | 461 | 562 | 5,976 | 69 | 349 | 128 | 141 | -- |
| „ 23 | 7,592 | 670 | 650 | 5,866 | 126 | 96 | 29 | 81 | 74 |
| „ 26 | 5,330 | 678 | 859 | 3,376 | 111 | 25 | 58 | 223 | – |
| Total in Sq. Miles. | 32·2 | 2·83 | 3·23 | 23·78 | ·48 | ·73 | ·33 | ·69 | ·11 |

With regard to the area shown as bare rock, however, Mr. Kilroe remarks that even here there is usually a sprinkling of grit and limestone pebbles, and that where the rock-surface is uneven, the "pockets" contain transported drift, while a thin, locally-formed clayey rubble occurs in many places where it is necessary to map the ground as rock. The "dry gaps" in the granite south of Carrickmines, to which reference has previously been made, are thus described:—"Two of these cut across the rock-ridge which is separated from the mountains by Kiltiernan valley. They run parallel to each other in a S.E. direction, and in the lowest part present just a noticeable slope towards the south. The more easterly, known as the Dingle Glen, is a steep-sided ravine with a strikingly fresh eastern face of rock, in parts almost vertical, and throughout strewn with recent granite talus. The ground above, sloping gently towards the gap on both sides, is almost bare rock, except on the S.W. side, where it carries a thin coating of local drift. The bottom of the glen, about 50 feet from the crest, is covered with recent alluvium, and near its exit southward occurs a deposit of clay with boulders of limestone as well as granite. That the very recently-formed appearance has been given to this glen by the rush of water attendant upon the melting of the ice sheet there can be little doubt. The deposit of boulder-clay at the southern exit, however, seems to me to preclude the conception that the glen owes its origin to any material extent to glacial denudation. The second glen, Glenamuck, is not so striking a feature, though the origin of both is in all probability identical; and at each end rests a covering of boulder-clay containing grit, black chert and other travelled pebbles, mingled with boulders and talus blocks of granite. Another short gully in the granite near Sandyford, of somewhat different character, must have been in existence before the close of the Glacial Period, as one of its rocky slopes is glaciated."

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In examining the frequently-described cliff-sections south of Killiney, Mr. Kilroe paid close attention to the proposed subdivision of these drifts into "Upper Boulder-clay," "Middle Glacial Sand and Gravel," and "Lower Boulder-clay," but found that these divisions were too changeable and impersistent to be used in mapping the deposits. He observed that bands of more or less stony clay and silt, with all the characteristics of boulder-clay are intercalated and "dovetailed" with the layers of sand and gravel; and found reason to doubt "whether the lowest visible boulder-clay in the whole extended section constitutes the original base of the sand and gravel deposit, if indeed a 'basement clay' in this sense have any existence here." The lowest visible band of clay, however, presents some peculiar characteristics. Though mostly dark grey or slate coloured, some portions of the clay are purple, passing into red, in such a manner as to suggest that the red colouration is due to progressive weathering. "A remarkable feature of the red boulder-clay at one point is, that it contains large irregular *masses* of purple boulder-clay, with sharply-defined outlines—true boulders, in some cases sharply fractured, the gaping cracks being filled with sand, gravel or clay from the surrounding matrix. These clay-boulders show lamination or a flaky structure, and are easily distinguishable from the surrounding red clay when once noticed, not only by a slight difference of colouring, but in this also, that the masses are highly calcareous and the containing clay not so. The stony contents of both—chiefly green grit and slate and granite fragments—are alike, from which, as well as from the fact that some of the enclosed masses show fringes coloured red around cores of purple clay, it is inferred that the red clay is a more highly oxidised form of the purple material. The alteration, however, is not usually by gradual encroachment of oxidation and decalcification from without, but through the matrix having undergone vicissitudes, re-arrangement, &c., not experienced by the included masses." Mr. Kilroe.

Mr. Kilroe considers that these remarkable clay-boulders afford material aid in unravelling the history and mode of deposition of the series. He finds that the peculiar boulder-clay which is extensively dug for brick- and tile-making at Kill of the Grange, 2¼ miles inland, W.N.W. of Killiney (fully described by Professor Sollas, and Mr. R. L. Praeger in *Irish Naturalist*, Dec. 1895) is "almost if not quite identical with, and strikingly similar to that which composes the included masses of the Killiney section," and therefore concludes "there can be little room to doubt that the masses have been severed from a deposit similar in every way to that at Kill . . . This being admitted, the conclusion is inevitable that the Kill of the Grange deposit dates further back, in the series of glacial episodes, than the Killiney sands and gravels, and is anterior to the *layers* of boulder-clay interstratified with them; and this leads to the further inference that the deposit in question is a true Lower Boulder-clay."

With regard to the sands and gravels of the Killiney section, which, as previous observers have noticed, are steeply tilted in one part of the section, and almost horizontal in another part,

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Mr. Kilroe.

Mr. Kilroe has noticed some curious features indicating the disturbance and breaking up of the deposits when frozen. "Thus, fissures were formed in stratified sand and gravel, and filled with dyke-like tongues of gravel or of clay, a remarkable example of which is to be seen in the sea-cliff at the railway station at Killiney. What is so remarkable in this instance is that while the clay-tongue is obviously stratified and the stratification is further marked by an included layer of gravel, the fissure seems to have been filled from beneath, a circumstance difficult to explain." In another place it was found that the red boulder-clay above described had been curiously invaded by coarse unstratified gravel or shingle, which had filled a gap about eight feet wide: the margins of the gap were vertical, and sharply jagged and rent, the shingle passing insensibly upward into stratified gravel which was in turn capped by an upper sandy clay. These and kindred facts lead Mr. Kilroe "to picture the phenomena attendant upon the decline of glacial conditions in this (Killiney) district as follows:—

1st.—A lower boulder-clay, broken up and denuded in connection with the formation of—
2nd.—Sands, gravels and boulder-clay layers.
3rd.—Breaking up of boulder-clay layers, and rearrangement of gravels.
4th.—Pipes, guts, or pot-holes in 3rd series.
5th.—Continuation of sand and gravel deposit.
6th.—Upper clay.

"Perhaps the best way of accounting for the sequence of phenomena, thus shown to be in some sense recognisable, is, by conceiving that, following the deposition of the lower boulder-clay, and during the melting of the great sheet of land-ice, there were deluges which carried off the finer matter (clay, silt, &c.), and deposited layers of stratified gravels, alternating with unassorted materials now forming boulder-clay; and, possibly, also temporarily-formed lakes with frozen margins, in which were laid down the finer sediments, into which stones were occasionally dropped from small floating ice-rafts or bergs." The detached clay masses are considered to have been torn from steep banks of frozen clay, eroded by these floods. Mr. Kilroe is opposed to the view that the recurrence of boulder-clay among the sand and gravel is here attributable to alternating advances and retrocession of the margin of the ice sheet.

The presence of marine shells, mostly fragmentary, which are sparsely scattered through both the lower boulder-clay and the gravels at Killiney, has been noted by many previous observers. Mr. Kilroe considers that the boulder-clay should be regarded as the source of these shells, "and, inferentially, that it, or the materials composing it, were originally laid down on the sea-floor and subsequently pushed up over the land"; and that, from the denudation of this clay, the shells in the gravels have been derived.

The upper boulder-clay of the Killiney section is yellowish and sandy, and in some places contains numerous large blocks of the local granite. It is usually greatly decalcified and oxidised, and,

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near Killiney Station, rests upon the truncated edges of sand and gravel beds, here highly inclined. "A short distance south of the station this clay seems to attain a thickness of some 30 feet, which is quite unusual in the entire section or elsewhere in the district. It is probable, therefore, that the top clay merges imperceptibly into one of the layers of the boulder-clay (or several layers combined) which are included in the sand and gravel series; for when these layers occur near the top of the section, they are so highly oxidised and decalcified as to become indistinguishable from the clay which caps the gravels, and for this reason is entitled to the appellation of 'Upper Boulder-clay.'" At many other places in the district a boulder-clay up to 10 or 12 feet in thickness was seen to overlie gravels, but whether this represents the upper clay of the Killiney section could not be determined. Mr. Kilroe.

After mentioning and stating objections to the various hypotheses which have been put forward to explain the Irish drifts, and especially their included marine shells and foraminifera in certain localities, Mr. Kilroe writes as follows:—

"Almost the only remaining probable hypothesis is that the materials of the Kill of the Grange clay, and similar clay at other points, has, as already mentioned, been pushed upward as *moraine profonde* from the Irish Sea bed, and if this view be accepted, it at once accounts for the fossil- and stone- contents of the clay and subsequently-deposited gravels. The great obstacle to the acceptance of that hypothesis, of course, is the prevalence of easterly striation—the only direction now noticeable. In its favour, however, it may be mentioned that in coming from the westward it could not have carried the materials of the Kill of the Grange clay; while these materials are exactly such as could have been accumulated on the sea-floor by glaciers descending from the marl plains of Antrim and Down, on the west, and those of the Solway region and Cheshire, probably, on the east, as well as from the glens of Down, Cumberland and Wales, during the approaching climax of glacial conditions. The objection to the material having been subsequently pushed up over Irish land is not insuperable if we conceive that such an accumulation of ice and *névé* occurred in the Cumbro-Cambrian region as, after filling up the Irish Sea, temporarily overmastered any ice-flow coming at the time from Central Ireland, and dragged the sea deposits inward over the present Irish coast line. This westerly flow from Cumberland would become reversed as the Irish ice-system grew, and would unite with an ice-stream flowing southward along the channel, as would also the new easterly ice-flow from Central Ireland. This last, continuing probably for a much longer period than that during which the westerly flow over-rode Irish land, would have obliterated all trace of the latter, except possibly in the spots where the lower boulder-clay occurs, where, however, striæ have not been found."

*Agricultural Notes.*—The prevalence of limestone detritus profoundly affects the character of most of the ground in this



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Mr. Kilroe. sheet. The fertility of the soils derived therefrom is manifest in the luxuriant park-timber and hedge-rows, the choice and succulent herbage, which deck the lower portions of the area. The boulder-clay soils and those covering the various deposits of limestone gravels are mostly rich brown loams, which, though in many cases highly retentive, do not manifest great need of artificial drainage.

The alluvial deposits consist of, or yield on weathering, rich sandy loams, bearing a luxuriant herbage, or equally luxuriant crops where tilled, all of which indicate the beneficial effects of occasional saturations of the soils with lime-charged waters, or of top-dressings with flood-silts drawn from limestone, occurring either as solid rock or drifted detritus.

Skirting the small areas of granite in the lower ground, and on the hill slopes below where the granite, slate, &c. protrude above the drift, the soils and sub-soils show a quantity of locally derived material, replacing or concealing the limestone boulder-clays. The soils in those places are poor in comparison with those derived from the limestone detritus, and bear, when not manured, a coarse, unpalatable herbage.

Several samples of soils and sub-soils were taken during the progress of the Survey, and are undergoing examination, the results of which will appear in the Memoir.

Mr. McHenry The area of forty-one square miles surveyed by Mr. McHenry lay almost entirely on the plain in the central part of Sheet 112, and therefore was mainly overspread by the limestone-boulder-clay, though diversified, as already described, in the western part by a fine esker-ridge, and by the valleys of the Liffey and Dodder with their post-glacial fluviatile deposits, and also by the low raised beach along its seaward margin. The central part of the city of Dublin is placed on this raised beach, or on the river-deltas conterminous with it, but the higher parts of the city, with most of its suburbs, are built upon the gentle slopes of boulder-clay which border these flats. Although the boulder-clay over the greater parts of the area is of the dark blue limestone-type, there is a marked change of character in certain parts of the mass as we approach the southern margin of the Carboniferous Limestone tract. Thus, in several good sections in the bank of the tributary streams on the southern side of the Dodder Valley between Rathfarnham and Firhouse, a dull purple tenacious clay is exposed, resembling that of the Kill of the Grange brick-pits (above described by Mr. Kilroe). This clay always contains a few fragmentary shells, just as at Kill of the Grange and Killiney, whereas no shells have been found in the normal limestone clay. In one of the stream-sections it was traced southward to Rockbrook, nearly three miles south of the Dodder, sometimes underlying bands of the normal limestone-clay; and it is highly suggestive of the close association of this clay with the shelly stratified drift, that we should find some of the principal exposures of the high-level shell-bearing gravels on the hill-slopes within a mile to the S. and S.E. of this place, and that at Larch Hill a patch of clay of similar character should be actually included in the gravels.

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Where the Dodder Valley cuts into the esker-ridge some fine sections are exposed along the river-banks. Mr. McHenry

At this point Mr. McHenry observes that the material of the esker has been entirely derived from the same source as the boulder-clay, the included stones being identical in character, and both showing a notable absence of the Leinster granite, although this local granite is very conspicuous in the late-glacial flood-gravels and subsequent high-level gravels of the Dodder, which rest on eroded surfaces of the esker-gravels in these sections.

Until the investigation has been carried beyond the limits of the present area there is room for uncertainty whether the current which deposited the gravel-ridge flowed northward or southward, but the probability is that it took the latter direction. The occurrence of a water-worn limestone surface beneath the esker, which has been previously mentioned (p. 187), is described by Mr. McHenry as follows:—

"There can be little doubt as to the origin of these gravels and sands. Unquestionably they are due to ice-rivers that flowed both on, in, and in many cases under the ice-sheet. In some cases these ice-rivers cut down through whatever slight covering of boulder-clay there may have been deposited on the solid rock, and washed off the original striæ. An instance of this was noticed in the quarry on the west side of the road leading from Green Hills northward, where 20 to 30 feet of gravel is seen resting directly on the Calp limestone, while in the north end of the quarry a thin stratum of boulder-clay rests on the still striated rock-surface, the sand and gravel of the esker resting on the boulder-clay."

With regard to the Late-glacial Flood-gravels, of which several small tracts were surveyed by him, Mr. McHenry remarks that these bear a close resemblance to the river-gravels both in composition and arrangement though differing in their position in respect to the existing valleys. In most of the places where they occur, both deposits have been extensively worked for building purposes and for pathway material.

The deltas formed where the principal streams open out upon the Raised Beach are necessarily shown on the one-inch map as forming part of this Beach, though sometimes rising slightly above its usual level. They are thus described by Mr. McHenry:—

"Along the shore where the Tolka, the Liffey, and the Dodder enter the sea, extensive fan-shaped deposits of gravel and sand have been laid down. Many extensive openings in them can be seen, the best being those now worked in the vicinity of the main-road to Blackrock, east of the Dodder. For its size, the Dodder appears to have deposited by far the greater proportion of these delta-gravels, this being no doubt due to its rapid fall from the Dublin Hills, causing more violent torrents in early post-glacial times, and to the enormous quantity of glacial material with which its ancient channel was choked.



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Mr. McHenry "There is a well-marked feature on both sides of the Liffey which defines the boundary of its river-deposits with the underlying boulder-clay. In all cases, during the excavations for main-drainage purposes, river-gravel was found to exist within the limit of this feature. In almost every instance the river-gravel rests directly upon the boulder-clay, but in a few cases it rests directly on the Carboniferous Limestone, as at the bottom of the new Hawkins Street shaft of the tunnel under the Liffey."

Mr. Seymour. The mountainous ground surveyed by Mr. Seymour on the southern margin of Sheet 112 included the summits of Three Rock (1,479 ft.) and Two Rock (1,699 ft.) Mountains; and Fairy Castle (1,763 ft.) and the lower hills to the westward, with the intervening valleys.

"The deposits of drift are chiefly confined to the valleys, the hilly ground being practically bare granite with a scanty covering of heather and peat. In the Larch Hill and Ticknock valleys, however, the boulder-clay runs up to heights of 1,090 ft. and 950 ft. respectively, the section in the former being 8–10 ft. thick at this elevation and full of striated limestone pebbles and boulders. . . . Kilmashogue Mountain (1,339 ft.) is almost entirely surrounded by gravel, and the outer boundary of this probably represents the line of a retreating glacier, between the front of which and the mountain slope, the washed morainic material would be deposited as gravel. Some of the steep lower slopes, on which no drift has lodged, are thickly strewn with large boulders of granite, and similar boulders frequently occur in the gravels, especially in their upper part. . . . South of Kilmashogue is another area of gravels, moundy in places, and reaching a maximum elevation of over 1,300 feet, which have long been noted for the numerous shell-fragments they contain."

A dry gap cutting the ridge on the east side of the Ticknock valley, similar to those at lower levels to the eastward, previously described, is remarked by Mr. Seymour to lie in an almost direct line with the great Montpelier Gap to the westward (in Mr. Wright's ground) and with another still farther west. To explain the much lower elevation attained by the drift on the mountain slopes outside the valleys, Mr. Seymour suggests that the western valleys being of gentle slope without any sharp rise, and lying also in the direction of the ice-flow, as indicated by the striæ, afforded an easy ascent for the drift-laden lower part of the ice, which could not rise upon the bluff slopes of the hill-shoulders.

The tract examined by Mr. Seymour in the N.W. corner of the sheet, forming part of the Carboniferous Limestone plain, is chiefly overspread with limestone-boulder-clay, with some minor kame-like mounds of gravel and protruding ridges of bare or nearly bare rock. The chief interest in this ground centres in the Liffey Valley, which trenches the plain and reveals many good sections in natural and artificial exposures on its steep slopes. It is in this tract that, as previously mentioned, the Liffey apparently diverges from its pre-glacial valley, and cuts a short looped cañon in the solid rock. Near this place the gravelly mounds which are believed to represent the northward

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prolongation of the Green Hills Esker, are intercepted by the present valley, and the diversion of the river may possibly have been connected with this circumstance. The easterly portion of the buried pre-glacial channel appears to be filled up chiefly with boulder-clay, as indicated in a deep lateral ravine and in well-borings in the S.W part of Phœnix Park; but in the western portion there is a thick mass of gravel, which is well seen in pits in the valley below Knockmaroon Lodge. In one of these pits, close to the ferry, numerous shell-fragments were found, associated as usual with far-travelled stones including the Ailsa Craig rock, and with streaks of brown clay. The drifts of the surrounding country appear to be devoid of shells, and no previous record of their occurrence in the Liffey valley is known. Mr. Seymour.

The mapping of the drifts on the peninsula of Howth was undertaken at the beginning of the field-season by Mr. Seymour and Mr. Wright, under the personal guidance of Mr. Lamplugh. It was found that the limestone-clay had practically enwrapped the lower slopes of the hill, though now in part stripped off by later erosion. The curious manner in which this material is "plastered" against the slopes has frequently attracted attention. The summit, however, is principally bare rock, with narrow "tongues" of drift in the hollows between the bosses of quartzite. These bosses are frequently ice-scored, especially on the quartz-veins, where the striæ are so fine that they become visible only after the application of some such colouring material as scraped lead-pencil to the smooth greasy-feeling white surface. The striæ indicate a general movement of the glaciating agent from about W. 30 N., but swing round the shoulders of the hill, where the ice-current has been deflected. The limestone-clay in the hollows is sometimes covered by a few feet of local detritus, probably in part glacial and in part a later storm-wash, and in some places this material alone is present. Mr. Seymour and Mr. Wright.

The thick mass of gravel and sand banked against the northern side of the hill at the village of Howth is one of the well-known shell-bearing drift-deposits of the Dublin district, and similar shell fragments also occur sparingly in the patches of boulder-clay on the eastern and southern slopes of the peninsula. The gravels at Howth attain their maximum development opposite a broad depression in the solid rocks, which runs south-eastward nearly across the headland, and they appear to be intimately related to this feature. To the eastward and westward of this hollow the stratified material diminishes rapidly in quantity and in texture, until it appears finally to thin out between an upper and lower band of boulder-clay.

In discussing the upper part of the boulder-clay of these sections Mr. Seymour remarks that it resembles the upper clay which he observed to be similarly associated with gravels in the other areas mapped by him, being less compact than the lower clay and generally found at the foot of more or less steep ascents. "It is almost certainly derived from material either in ice englacial), or attached to the soles of icebergs: in the first case the material being let down *in situ* by the gradual melting of the

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Mr. Seymour and Mr. Wright.

ice, and in the second case dropped from melting bergs in lakes." The second explanation appears to him to be the more probable, as the upper clay within the area surveyed by him occurred in places where temporary lakes were likely to be formed during the recession of the ice.

The supposed high-level raised beach near the Bailey Lighthouse, mentioned in the *Survey Memoir* (p. 67), proves to be a "kitchen-midden," containing only edible shells, broken bones of domestic animals, and other indications of artificial accumulation. The only trace of post-glacial marine submergence in this, as in other parts of the district, is the conspicuous Raised Beach of shingle and sand with recent shells, rising 10 to 20 feet above present sea level, which forms the low spit connecting Howth with the mainland. On the rocky outer shores of the headland and of Ireland's Eye, this beach is indicated in places by an eroded rock-shelf and by ancient caves. A cemented mass of old beach-material was observed in one of these caves on Ireland's Eye, adhering to the rock-walls at the usual level of the Raised Beach.

On the mainland west of Howth, the plain of boulder-clay is deeply furrowed by broad drainage hollows, regarding which Mr. Seymour notes: "none of the streamlets now flowing in them could possibly produce such features; they are all 'mis-fits,' and the principal work of erosion must be attributed to a time after the glacial period, when much larger streams flowed through these valleys."

Mr. Wright.

The area surveyed by Mr. Wright in the northern part of Sheet 112, while mainly overspread with the limestone-boulder-clay, was broken in places by outcrops of the solid limestone, and by irregular mounds and short esker-like ridges of stratified drift, the latter being associated, in the vicinity of the Tolka river, with gravelly flats. That these stratified drifts were directly of glacial origin was frequently evident from the manner in which they merged gradually into clayey unstratified material full of scratched stones, which was inseparable from the normal boulder-clay of the district.

In the mountainous ground examined by Mr. Wright in the south-western part of Sheet 112 the drifts were much more complicated, and stratified material was much more abundant. Gravelly deposits, composed principally of limestone, but often with a plentiful admixture of the local granite, and with a few far-transported stones, including Chalk flints, Old Red conglomerate, Silurian grit, and occasionally the Ailsa Craig rock, and where unweathered, with shell-fragments, formed moundy ground on the slopes of the hills up to the 1,250 ft. contour. In descending the slopes these gravels appear usually to pass beneath an upper boulder-clay, though the sections are rarely sufficiently continuous to show this relationship clearly. From one of the high-level gravel pits at Larch Hill no less than forty-two species of shells have been obtained by Mr. Hinch, a persevering amateur student of these shelly deposits.

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The fine high-level notch in the solid rock on the southern side of Montpelier Hill, to which reference was made in the introductory part of this report, is described by Mr. Wright as follows:— Mr. Wright.

"This remarkably steep gap or pass, which is 530 yards long, connects the valleys of Killakee and Glenasmole. Its sides are strewn with blocks of granite, which form a talus at the base, and their slope varies from 20°—35°. The height of the summit is 1035 feet, but it is probably raised considerably above its original height by the falling in of *débris* from the sides. The gap is almost dry, there being only two small rivulets trickling, one from each end, in opposite directions, that on the west being soon joined by a larger stream from the moorland above.

"The gravels associated with this gap form a continuous deposit, lying between the 800 and 1250 ft. contours, which may be roughly divided into an upper and a lower series. The upper series forms a thin covering, with scattered mounds, on the moor overlooking the gap on the south and on Montpelier Hill on the north. The lower series consists of two mounds, one on each side of the valley at the westerly end of the gap. At Ann Mount, in Glenasmole, the gravels also occur at two levels, but the upper level in this case is the same as the lower one in the Montpelier Valley."

## II. MAPS PUBLISHED.

The following is a list of the revised one-inch maps issued by the Geological Survey of Ireland during the past year:—

Sheets Nos. 46, 61, 67, 79, 115, 117, 118, 125, 126, 127, 134, 135, 143.

The revisions are almost wholly confined to the Ordovician and Silurian Rocks.

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## APPENDIX A.

CATALOGUE of TYPES and FIGURED SPECIMENS of BRITISH FOSSIL PHYLLOCARIDA preserved in the MUSEUM of PRACTICAL GEOLOGY, London.

By H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets, *e.g.* (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The figures in square brackets [7509] correspond to the number in the Museum Register.

The following abbreviations are employed:—

M. G. S.: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monographs of the Palæontographical Society, London.

Q. J. G. S.: Quarterly Journal of the Geological Society of London.

Geol. Mag.: The Geological Magazine, London.

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**Caryocaris Marrii**, Hicks.
Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiv., f. 16, p. 92.
Arenig. [7509] Skiddaw, Cumberland.

**Caryocaris Wrightii**, Salter.
Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiv., figs. 11, 12, p. 89.
Skiddaw Slates. [7508, 7509] Skiddaw.

**Ceratiocaris aptychoides**, *vide* **Dithyrocaris ?**

**Ceratiocaris canaliculata**, Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 3, p. 32.
Upper Ludlow. [7481] Whitecliff, Ludlow.

**Ceratiocaris cassia**, Salter.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 7 *c–e*, p. 58.
Lower Ludlow. [7451] Trippleton, Leintwardine.



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**Ceratiocaris cassioides**, Jones and Woodward. T.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 6, p. 59.
Lower Ludlow. [7480] Leintwardine, Shropshire.

**Ceratiocaris gigas** (Salter, M. S.), Jones and Woodward. T.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. iii., f. 1, p. 24.
Lower Ludlow. [7452] Danefield, Kington, Herefordshire.

**Ceratiocaris halliana**, Jones and Woodward. T.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. ii., figs. 1–4, p. 26.
Lower Ludlow. [7453–7456] Church Hill, Leintwardine and Bow Bridge, Ludlow.

**Ceratiocaris leptodactylus** (M'Coy).
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vi., figs. 6-9, p. 14.
Wenlock Shale (Coniston Grit). [7459, 7855-7857] Helm Knot, Dent, Yorkshire.

**Ceratiocaris longa**, Jones and Woodward. T.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. xi., f. 5, p. 43.
Lower Ludlow. [7468] Leintwardine.

**Ceratiocaris minuta** ? Jones and Woodward. T.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. xi., f. 10, p. 47.
Lower Ludlow. [7478] Leintwardine.

**Ceratiocaris Murchisoni** (Agassiz).
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. iii., figs. 4, 7, p. 16.
Lower Ludlow. [7473, 7476] Leintwardine.

**Ceratiocaris Murchisoni** (Agassiz). T.
H. Woodward, Geol. Mag., 1866, pl. x., f. 9, p. 203. Refigured as **Ceratiocaris tyrannus**: Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vi., f. 11, p. 20.
Wenlock Shale (Coniston Grit). [7472] Casterton Low Fell, Kirkby Lonsdale.

**Ceratiocaris papilio**, Salter. T.
J. W. Salter, Ann. Mag. Nat. Hist., vol. v., 1860, p. 154, f. 1.
Lower Ludlow. [7479] Logan Water, Lesmahagow.

**Ceratiocaris reticosa**, Jones and Woodward. T
Jones and Woodward, Geol. Mag., 1895, pl. xv., f. 1 *a*, *b*, p. 539.
Ludlow. [4435] Locality ?

**Ceratiocaris robusta**, Salter.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. x., f. 10, p. 44.
Lower Ludlow. [7471] Leintwardine.

**Ceratiocaris salteriana**, Jones and Woodward. T
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. vii., f. 1 *a*, *b*, p. 55.
Lower Ludlow. [7477] Bow Bridge, Ludlow.

**Ceratiocaris solenoides**, M'Coy.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. viii., f. 9 *a*, *b*, p. 52.
Upper Ludlow. [7458 Benson Knot, Kendal.

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**Ceratiocaris stygia**, Salter.
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. xi., f. 3, p. 38.
Lower Ludlow. [7469] Leintwardine.

**Ceratiocaris tyrannus** (Salter, M. S.), Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl iii., figs. 2, 3, 5, 8, p. 22. (See also *C. murchisoni.*)
Lower Ludlow. [7474, 7475] Leintwardine.

**Dictyocaris Ramsayi**, Salter. **T.**
J. W. Salter, M. G. S., Edinburgh, 1861, pl. ii., f. 20, p. 133.
Salter and Woodward, Chart Foss. Crust., 1865, p. 17.
Upper Silurian. [7483] North Esk Reservoir, Carlops.

**Dithyrocaris Colei**, Portlock. **T.**
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xii., figs. 1–5, p. 314.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxiii., figs. 2–5; pl. xxiv., figs. 2, 4, p. 163.
Carboniferous Shales. [6261–6263, 6265] Clogher, Tyrone.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxvii., f. 5, p. 168.
Carboniferous Shales. [6260] Clogher, Tyrone.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xii., f. 6, p. 315.
H. Woodward, Geol. Mag., 1865, pl. xi., f. 8, p. 401.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxvi., f. 44, p. 194.
Carboniferous Shales. [6264] Co. Derry.

**Dithyrocaris orbicularis**, Portlock. **T.**
J. E. Portlock, Rep. Geol. Londonderry, 1843, p. 316.
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxiv., f. 3, p. 168.
Lower Carboniferous. [6266] White Water River, Co. Derry.

**Dithyrocaris testudinea** (Scouler).
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xix., f. 9, p. 145.
Lower Carboniferous. [6268] Glasgow Coalfield.

**Dithyrocaris tricornis** (Scouler).
Jones and Woodward, Mon. Pal. Soc., vol. lii., 1898, pl. xxvii., f. 2 *a–c*, p. 170.
Lower Carboniferous. [7519] East Kilbride, Lanarkshire.

**Dithyrocaris ? aptychoides**, Salter. **T.**
J. W. Salter, Q. J. G. S., vol. viii., 1852, pl. xxi., f. 10, p. 391. Described as **Ceratiocaris aptychoides**, J. W. Salter, Ann. Mag. Nat. Hist., vol. v., 1860, p. 161; and as **Peltocaris aptychoides**, Salter, Q. J. G. S., vol. xix., 1863, p. 88 (text figure); Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xvi., f. 3, p. 113.
Llandeilo Flags. [7507] Duff Kennel, Dumfriesshire.

**Emmelezoe crassistriata**, Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. viii., f. 3, p. 70.
Upper Ludlow. [7457] Combe Wood, Presteign.

**Emmelezoe maccoyana**, Jones and Woodward. **T.**
Jones and Woodward, Mon. Pal. Soc., vol. xli., 1888, pl. viii, f. 2, p. 71.
Lower Ludlow. [7470] Leintwardine.

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**Hymenocaris vermicauda**, Salter. **T.**

J. W. Salter, M. G. S., North Wales, 1866, pl. ii., figs. 1, 2, p. 293.
Lower Lingula Flags. [7502] Penmorfa, Tremadoc.

J. W. Salter, M. G. S., North Wales, 1866, pl. v., f. 25, p. 293.

Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiii., f. 9, p. 74.
Lower Lingula Flags. [7503] Moel-y-gest, Tremadoc.

**Hymenocaris vermicauda**, Salter.

Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiii., figs. 8, 13, p. 74.
Lingula Flags. [7505, 7504] Portmadoc.

**Hymenocaris vermicauda** ? (tracks of).

J. W. Salter, Q. J. G. S., vol. x., 1853, p. 210. (Text figure.)

J. W. Salter, M. G. S., North Wales, 1866, pl. i., p. 294.
Lower Lingula Flags. [7520] Tremadoc, N Wales.

**Lingulocaris lingulæcomes**, Salter.

Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xiv., f. 4, p. 81.
Upper Llandeilo. [7510] Builth.

**Peltocaris anatina**, Jones and Woodward.

Jones and Woodward, Mon. Pal. Soc., vol. xlvi., 1892, pl. xvi., f. 4, p. 114.
Llandeilo Flags. [7506] Moffat ?

**Peltocaris aptychoides**, *vide* **Dithyrocaris** ?

**Peltocaris** ? (tracks of).

J. W. Salter, Q. J. G. S., vol. xix., 1863, p. 94. (Text figure.)
Llandeilo Flags. [7521] Wilmington Dingle, Chirbury, Salop.

**Salterina [Salterella] pholadiformis** (Salter, M. S.), Jones and Woodward. **T.**

Jones and Woodward, Geol. Mag., 1888, p. 453. (Text figure.)
Lower Limestone Shales. [7518] Berwick-on-Tweed.

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## APPENDIX B.

### Catalogue of Types and Figured Specimens of British Palæozoic Echinodermata preserved in the Museum of Practical Geology, London.

By H. A. Allen, F.G.S.

Each specimen is entered under the name given to it when first figured. When the author's name is placed in brackets, *e.g.* (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The figures in square brackets [7009] correspond to the number in the Museum Register.

The following abbreviations are employed:—

M. G. S.: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monographs of the Palæontographical Society, London.

Pal. Foss.: Figures and Descriptions of the Palæozoic Fossils of Cornwall, Devon, and West Somerset, by John Phillips, 1841.

Q. J. G. S.: Quarterly Journal of the Geological Society of London.

Geol. Mag.: The Geological Magazine, London.

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#### Cystidea.

**Caryocystites granatum** (Wahlenberg).
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 4, p. 512.
Caradoc. [7406] Rhiwlas, Bala.

**Caryocystites Litchi**, Forbes.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 2 *a–c*, p. 514. Refigured as **Sphæronites Litchi**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., figs. 3? 4, p. 286. (Figs. 3 and 4 *c* referred to *S. munitus*.)
Caradoc. [7431] Sholeshook, Haverfordwest.

**Caryocystites? munitus**, Forbes. **T.**
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 3 *a*, *b*, p. 515. Refigured as **Sphæronites munitus**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 5, p. 285.
Caradoc. [7429] Rhiwlas, Bala.

**Caryocystites pyriformis**, Forbes. **T.**
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxi., f. 1 *a–d*, p. 515. Refigured as **Sphæronites pyriformis**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., figs. 1, 2, p. 285.
Caradoc. [7432] Rhiwlas, Bala.



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**Echinocystites pomum**, W. Thomson. T.
Wyville Thomson, Edin. New Phil. Journ., N. S., vol. xiii., 1861, pl. i., f. 3, p. 109.
Lower Ludlow. [7385] Leintwardine.

**Echinoencrinites armatus**, Forbes. T.
E. Forbes, Mem. Geol. Survey, vol. ii., pt. 2, 1848, pl. xviii., figs. 1-6, 11-13; pl. xix., figs. 1, 4, 6, p. 507.
Wenlock Limestone. [7381-4] Walsall.

**Echinoencrinites baccatus**, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xvii., figs. 1, 3, 4, p. 506.
Wenlock Limestone. [7380] Walsall.

**Echinosphærites arachnoideus**, *vide* **Sphæronites.**

**Hemicosmites oblongus**, (Pander).
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xx., f. 6, p. 511.
J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 11, p. 288.
Caradoc. [7426] Sholeshook, Haverfordwest.

**Hemicosmites pyriformis**, v. Buch.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xx., figs. 2-5, p. 511. Refigured as **H. rugatus**, Forbes: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 12, p. 288.
Caradoc. [7421, 7422] Gt. Cresswell, St. Clare; Sholeshook.

**Hemicosmites rugatus**, *vide* **H. pyriformis.**

**Pleurocystites Rugeri**, Salter. T.
J. W. Salter, M. G. S., North Wales, 1866, pl. xxiii., f. 5, p. 288.
Caradoc. [7434] Blaen-y-cwm, nr. Llandovery.

**Sphæronites arachnoideus**, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxii., f. 4, p. 518. Refigured as **Echinosphærites**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 8, p. 287.
Caradoc. [7405] Sholeshook, Haverfordwest.

**Sphæronites aurantium** (Gyllenhal).
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxii., f. 1 *a*, *b*, p. 516. Fig. 1 *b* refigured as **S. stelluliferus**: J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 6, p. 287.
Caradoc. [7428] Sholeshook, Haverfordwest.

**Sphæronites Litchi**, *vide* **Caryocystites.**

**Sphæronites munitus ?** Forbes.
J. W. Salter, M. G. S., North Wales, 1866, pl. xx., figs. 3, 4 *c*, p. 286.
Caradoc. (See also *Caryocystites.*) [7430] Sholeshook, Pembrokeshire.

**Sphæronites ? punctatus**, Forbes. T.
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxii., f. 2 *a*, *b*, p. 518.
J. W. Salter, M. G. S., North Wales, 1866, pl. xx., f. 7, p. 286.
Caradoc. [7433] Rhiwlas, Bala.

**Sphæronites pyriformis**, *vide* **Caryocystites.**

**Sphæronites stelluliferus**, *vide* **S. aurantium.**

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CRINOIDEA.

**Actinocrinites amphora**, (Goldfuss).
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., figs. 4 *a*, *b*, 5 *a*, *b* p. 347.
Carboniferous Limestone. [7615] Cleenish, Tonyloman, Fermanagh.

**Actinocrinus ? Batheri**, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., 1898, vol. lii., pl. xxxii., figs. 2, 2 *a*, *b*, 3, 3 *a*, *b*, p. 222.
Upper Devonian (Marwood Beds). [7145, 7146] Braunton, North Devon.

**Actinocrinites decadactylus ?** Goldfuss.
J. E. Portlock, Rep. Geol. Londonderry, 1843, p. 349.
Carboniferous Limestone. [7629] Stewartstown, Tyrone.

**Actinocrinites icosidactylus**, Portlock. **T.**
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 7, p. 348.
Carboniferous Limestone. [7628] Hook, Wexford.

**Actinocrinus Porteri**, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxi., figs. 1, 1 *a* 2, 5 ; pl. xxxii., f. 1, p. 220.
Upper Devonian. [7138–7141] North Devon.

**Actinocrinites ? retiarius**, Phillips. **T.**
R. I. Murchison, "Silurian System," pt. 2, 1837, pl. xvii., f. 7, p. 674.
Wenlock Limestone. [7379] Dudley.

**Adelocrinus hystrix**, Phillips. **T.**
J. Phillips, Pal. Foss., 1841, pl. xvi., f. 42 *a*, *b*, p. 30.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxx., f. 4, p. 224.
Upper Devonian (Pilton Beds). [7157] Brushford, N. Devon.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxx., figs. 7, 7*a*, p. 224.
Upper Devonian (Pilton Beds). [7156] Braunton.

Crinoid, Auxiliary arm of
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 3, p. 346.
Caradoc. [7390] Desertcreat, Tyrone.

Crinoidal Column.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 2 *a*, *b*, p. 345.
Caradoc. [7392] Desertcreat, Tyrone.

**Cupressocrinus crassus**, Goldfuss.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiv., figs. 4, 4 *a*, p. 207.
Middle Devonian. [7087] Newton Bushel.

**Cyathocrinus acinotubus ?** Angelin.
F. A. Bather, Ann. Mag. Nat. Hist., vol. ix., 1892, p. 211. (Text figure 5.)
Wenlock Limestone. [7375] Dudley.

**Cyathocrinus ? ellipticus**, Phillips. **T.**
J. Phillips, Pal. Foss., 1841, pl. xvi., f. 49 *a–d*, p. 32.
Upper Devonian. [7147] Petherwin, Cornwall.

**Cyathocrinus ? macrodactylus**, Phillips, **T.**
J. Phillips, Pal. Foss., pl. xv., f. 41*e*, p. 29. Refigured as **Taxocrinus macrodactylus**: G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiii., f. 2, p. 215.
Upper Devonian (Pilton Beds). [7148] Pilton, North Devon.

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**Gilbertsocrinus simplex**, Portlock. T.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., f. 5 *a*, *b*, p. 351.
Carboniferous Limestone. [7615] Fermanagh.

**Glyptocrinus ? (Cœlocrinus) basalis**, M'Coy.
J. W. Salter, M. G. S., Geol. North Wales, 1866, pl. xxiii., f. 4, 4 *a*, p. 283.
Caradoc. [7388] Guilsfield, near Meifod.
J. W. Salter, M. G. S., Geol. North Wales, 1866, pl. xxiii., f. 4 *b*, p. 283.
Caradoc. [7389] Gwrelddian, Llanwddyn.

**Hexacrinus depressus**, Austin. T.
T. and T. Austin, "Recent and Fossil Crinoidea," 1843, pl. vi., f. 2 *a–e*, p. 49.
Middle Devonian. [7089, 7091] Newton Bushel.

**Hexacrinus interscapularis** (Phillips).
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxi., f. 2; pl. xxii., figs. 2, 2 *a*, p. 190. (See also *Platycrinus interscapularis*.)
Middle Devonian. [1549, 7090] Bradley and Newton Abbot.

**Hexacrinus macrotatus**, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 3 *a*, *d*, p. 50.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxii., f. 6, p. 192. (See also *Platycrinus tuberculatus*).
Middle Devonian. [6880] Newton Bushel.

**Hexacrinus melo**, *vide* **Platycrinus interscapularis.**

**Hexacrinus ? pentangularis**, Austin. T.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. vii., f. 1 *a–c*, p. 51. Refigured as **Hexacrinus quintangulus**, G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiii., figs. 6, 6 *a*, *b*, p. 198.
Middle Devonian. [7095] Newton Bushel.

**Hexacrinus perarmatus**, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxii., f. 10, p. 194.
Middle Devonian. [6879] Newton Bushel.

**Hexacrinus quintangulus**, *vide* **Hexacrinus ? pentangularis.**

**Hexacrinus Vicarii**, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiii., f. 4, p. 197. (See also *Platycrinus pentangularis ?*).
Middle Devonian. [7093] Newton Bushel.

**Hydreionocrinus ? globularis**, de Koninck. T.
L. de Koninck, Bull. Acad. Roy. Bruxelles, ser. 2, t. iv., 1858, pl. ii., figs. 1–4, p. 93. "The Geologist," vol. i, 1858, pl. iv., figs. 1–4, p. 180.
Carboniferous Limestone (*Productus*-bed). [7440] Lesmahagow.

**Hydreionocrinus scoticus**, de Koninck. T.
L. de Koninck, Bull. Acad. Roy. Bruxelles, ser. 2, t. iv, 1858, pl. ii., figs. 6, 7; p. 93. "The Geologist," vol. i., 1858, pl. iv., f. 6, 7, p. 179.
Carboniferous Limestone (*Productus*-bed). [7439] Lesmahagow.

**Platycrinus granulatus**, Miller.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. iii., f. 2 *m*, p. 33.
Carboniferous Limestone. [7630] Hook Point, Wexford.

**Platycrinites granulatus**, Miller.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., f. 4, p. 350.
Carboniferous Limestone. [7631] Hook Point, Wexford.

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**Platycrinus interscapularis**, Phillips. **T.**
J. Phillips, Pal. Foss., pl. xiv., f. 39 *a–d*, p. 28. Refigured as **Hexacrinus melo**, Austin, **T.** "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 1 *a–e*, p. 48; and as **Hexacrinus interscapularis**: G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxi., figs. 1, 1 *a–d*, p. 190.
Middle Devonian. [7088] Newton Bushel.

**Platycrinites lævis**, Miller.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. i., f. 1 *d*, *e*, *f*, *i*, *l*, *n*, p. 8.
Carboniferous Limestone. [7632–7634] Hook Point, Wexford.

**Platycrinus pentangularis** ? Phillips.
J. Phillips, Pal. Foss., pl. lx., f. 29**, p. 135. Refigured as **Hexacrinus Vicarii**, G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiii., f. 5, p. 197.
Middle Devonian. [7092, 7093] Newton Bushel.

**Platycrinites spinosus**, Austin. **T.**
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. i., f. 2 *p*, *q*, p. 19.
Carboniferous Limestone. [7663] Hook Point, Wexford.

**Platycrinites trigintidactylus**, Austin. **T.**
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. iii., f. 1 *b*, p. 30.
Carboniferous Limestone. [7664] Hook Point, Wexford.

**Platycrinus tuberculatus** ? Phillips.
J. Phillips, Pal. Foss, pl. lx., f. 39,* p. 134. Refigured as **Hexacrinus macrotatus**, Austin, **T.**, "Rec. and Foss. Crinoidea," 1843, pl. vi., f. 3 *b*, p. 50; G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxii., f. 8, p. 192.
Middle Devonian. [7094] Newton Bushel.

**Poteriocrinus conicus**, Phillips.
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 3 *c*, p. 82.
Carboniferous. [7606] Clifton, Bristol.
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., f. 12, p. 350.
Carboniferous. [7602] Fermanagh.

**Poteriocrinus dactyloides**, Austin. **T.**
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 7, p. 85.
Carboniferous Limestone. [7604] Hook Point, Wexford.

**Poteriocrinus isacobus**, Austin. **T.**
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. viii., f. 4 *a–d*, p. 74.
Carboniferous Limestone. [7605] Hook Point, Wexford.

**Poteriocrinus latifrons**, Austin. **T.**
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 4, p. 82,
Carboniferous Limestone. [7603] Mendip Hills.

**Poteriocrinus quinquangularis**, Austin. **T.**
T. and T. Austin, 'Rec. and Foss. Crinoidea," 1843, pl. x., f. 2 *a–e*, p. 80
Carboniferous Limestone. [7608–7611] Hook Point, Wexford.

**Poteriocrinus radiatus**, Austin. **T.**
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. x., f. 1 *a*, *b*, p. 79.
Carboniferous Limestone. [7614] Hook Point, Wexford.

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**Poteriocrinus rostratus**, Austin. **T.**
T. and T. Austin, "Rec. and Foss. Crinoidea," 1843, pl. ix., f. 2 *b*, *c*, p. 75.
Carboniferous Limestone. [7613, 7612] Hook Point, Wexford.

**Poteriocrinus** sp.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxv., f. 4. p. 228.
Upper Devonian (Marwood Beds). [7155] Braunton Down, N. Devon.

**Poteriocrinus** sp.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxvi., figs. 9, 9 *a*, p. 228.
Upper Devonian (Marwood Beds). [7154] Braunton Down, N. Devon.

**Rhodocrinus (Acanthocrinus)** sp.
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiv., figs. 6, 6 *a*, p. 204.
Middle Devonian. [7096] Newton Bushel.

**Rhodocrinus** ?
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxi., f. 3 *a–d*, p. 217.
Upper Devonian (Marwood Beds). [7142, 7143] North Devon.

**Scaphiocrinus** ? **inordinatus** ? Whidborne.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiv., f. 7, p. 230.
Upper Devonian (Marwood Beds). [7151] Braunton, North Devon.

**Scaphiocrinus** ? **plumifer**, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxvi., figs. 1, 1 *a*, p. 228.
Upper Devonian (Marwood Beds). [7153] Braunton, North Devon.

**Scaphiocrinus** sp.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiv., figs. 8, 8 *a*, p. 231.
Upper Devonian (Marwood Beds). [7152] Braunton, North Devon.

**Sphærocrinus geometricus** (Goldfuss).
G. F. Whidborne, Mon. Pal. Soc., vol. xlix., 1895, pl. xxiv., f. 8, p. 211.
Middle Devonian. [6878] Newton Bushel.

**Taxocrinus macrodactylus** (Phillips).
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxxiii., figs. 3, 3*a*, 4, 4*a*, p. 215. (See also *Cyathocrinus ?*).
Upper Devonian (Marwood Beds). [7149, 7150] North Devon.

**Trochocrinites lævis**, Portlock. **T.**
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xv., f. 1, p. 345.
Caradoc. [7391] Desertcreat, Tyrone.

## Edrioasteroidea.

**Agelacrinites buchianus**, Forbes. **T.**
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, pl. xxiii., figs. 1-14, p. 521. Figs. 2 and 3 refigured, J. W. Salter, M. G. S., Geol. North Wales, 1866, pl. xx., f. 13, p. 291. Figs. 1-9 refigured as **Edrioaster**, F. A. Bather, Geol. Mag., 1900, plates viii-x. and text figures, pp. 193-204. Fig. 1 refigured, O. Jaekel, "Stammesgeschichte der Pelmatozoen," vol. i., 1899, p. 45 (text figure).
Caradoc. [7403, 7404] 2 mls. W. of Ysputty Evan, Denbighshire.



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**Edrioaster**, *vide* **Agelacrinites.**

**Lepidodiscus Milleri**, Sharman and Newton. **T.**
G. Sharman and E. T. Newton, Q. J. G. S., vol. xlviii., 1892, pl. ii., p. 150.
Carboniferous Limestone. [7662] River Irthing, Cumberland.

ASTEROIDEA.

**Asterias primæva**, Salter. *Vide* **Palæaster obtusus.**

**Eugaster ? perarmatus** (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxvii., figs. 6, 6 *a*, p. 209.
Upper Devonian (Pilton Beds). (7163] Braunton Down.

**Palæaster asperrimus**, Salter. **T.**
J. W. Salter, Ann. Mag. Nat. Hist., vol. xx., 1857, p. 325.
J. W. Salter, M. G. S., North Wales, 1866, pl. xxiii., f. 2, p. 289.
Caradoc. [7435] Quakers' Burial Ground, Welshpool.

**Palæaster coronella**, Salter. **T.**
J. W. Salter, Ann. Mag. Nat. Hist., vol. xx., 1857, p. 326.
Upper Llandovery. [7402] Gunwick Hill, Malvern.

**Palæaster longimanus**, Whidborne. **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxvi., figs. 1, 1 *a*, 2, 3, 3 *a*, *b*, p. 204.
Upper Devonian (Pilton Beds). [7162–7164]
Park near Braunton, and Baggy Point, North Devon.

**Palæaster (Uraster) obtusus**, Forbes.
J. W. Salter, Ann. Mag. Nat. Hist., vol. xx., 1857, p. 326.
J. W. Salter, M. G. S., North Wales, 1866, pl. xxiii., f. 1, p. 289.
Caradoc. (See also *Uraster*.) [7436] Moel-y-Garnedd.

**Protaster granifer** (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxvi., figs. 5, 5 *a*, 6, 6 *a*, p. 207.
Upper Devonian (Pilton Beds). [7165, 7166] North Devon.

**Protaster ? (Drepanaster) scabrosus**, Whidborne, var. **T.**
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxviii., figs. 1, 1 *a*, *b*, 2, 2 *a*, *b*, p. 208.
Upper Devonian. [7167, 7168] Croyde, N. Devon.
G. F. Whidborne, Mon. Pal. Soc., 1898, pl. xxix., figs. 2, 2 *a*, p. 208.
Upper Devonian (Pilton Beds). [7169] Braunton Down, N. Devon.

**Uraster obtusus**, Forbes. **T.**
E. Forbes, M. G. S., vol. ii., pt. 2, 1848, p. 463.
E. Forbes, M. G. S., Decade 1, 1849, pl. 1, f. 3, p. 2.
Caradoc. (See also *Palæaster*.) [7437] Waterford.

OPHIUROIDEA.

**Ophiurella ? gregaria** (Whidborne). **T.**
G. F. Whidborne, Mon. Pal. Soc., lii., 1898, pl. xxviii., f. 3, p. 210.
Upper Devonian (Pilton Beds). [7162] Braunton Down, N. Devon.

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ECHINOIDEA.

**Cidaris benburbensis**, Portlock. T
J. E. Portlock, Rep. Geol. Londonderry, 1843, pl. xvi., figs. 10, 10 *a*, *b*, 11, p. 352.
Carboniferous Limestone. [7659] Benburb, Tyrone.

**Protocidaris acuaria** (Whidborne). T.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxv., figs. 1, 1 *a*, *b*, 2, 2 *a*, p. 203.
Upper Devonian (Pilton Beds). [7158, 7159] East of Barnstaple.

**Lepidesthes ? devenicans**, Whidborne. T.
G. F. Whidborne, Mon. Pal. Soc., vol. lii., 1898, pl. xxiv., figs. 1, 2; pl. xxv., f. 3 *a–f*, p. 200.
Upper Devonian (Pilton Beds). [7160, 7161] East of Barnstaple.

**Melonites Etheridgii**, Keeping. T.
W. Keeping, Q. J. G. S., vol. xxxii., 1876, figs. 1–6, p. 397.
Carboniferous Limestone. [6577] Clitheroe.

**Palæchinus gigas**, M'Coy.
R. T. Jackson, Bull. Geol. Soc. America, vol. vii., 1896, pl. vii., figs. 38, 39, p. 204.
Carboniferous Limestone. [6576] Clitheroe, Lancashire.

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# INDEX.


## A

Aberfeldy, 167.
Achilty, 111.
Agates, Indian, 93.
Agriculture, 16, 33, 53, 98, 103, 127, 132, 147, 148, 193.
Alderton, 59, 60.
Allen, H. A., 91, 95, 200, 204.
Alness, 3.
Alnöite, 69.
Alluvium, 10.
Ammanford, 43.
Amman Valley, 51.
Amphibolite, 101, 120, 121, 122.
Analyses, 72–91.
Andesites, 134, 135, 136, 138.
Aqueduct of Birmingham Waterworks, 60.
Arenig, 17, 65.
Argyll, 118, 149.
Arran, 178.
Asteroidea, 210.
Atholl Forest, 157.
Atkinson, J., 75.
——— M. W., 75.
Augen-gneiss, 106, 108, 111.
Augite-diorite, 97, 140, 141.
Axholme, Isle of, 64.
Axminster, 54–56, 58.
——— and Lyme Regis Railway, 53.
Aymestry Limestone, 62.

## B

Bagshot Beds, 56–58.
Bala Beds, 61.
Barrow, G., 66, 92, 151, 152 157–165, 183.
Barry, C., 83.
Bell, A., 185.
Bemrose, H. H. Arnold, 10.
Ben Vrackie, 172.
Biddulph Valley, 6, 7, 12.
Bindown, 29, 30.
Birmingham Waterworks, 60.
Bishopston, 52.
———Beds, 41.
Black Mountains, 50.
Blackadder, 180.
Blair Atholl, 157, 168.
Blake, J. H., 5, 92.
Bollin Valley, 12–14.
Boulders in Drift, Cheshire, 11.
Boulder Clay, Upper and Lower, 191, 193.
Boulder Clay, Derbyshire, 9; Cheshire, 10; Scotland, 114, 127, 132, 152–155; Dublin, 185 *et seq.*
Bovey Basin, 57, 58.
Boveysand, 29.
Boyd, L., 93.
Brecknock Beacons, 50.
Brickmaking, 16.
Brixham, 28.
Broadford Beds, 143.
Brögger, Dr. W. C., 70.
Brownstones, 39, 40.
Brynamman, 43.
Buchite, 152.
Bunter, 8.
Bynack, 160.
Bynea Brick-works, 53.

## C

Caban Group, 61.
Camborne, 23, 25.
Cambrian, 131.
Camptonite, 69, 70.
Cantrill, T. C., 5, 34–44, 50, 51, 60–64, 71, 80.
Carbis Bay, 19, 33.
Carboniferous, 5, 30, 63.
——— Limestone, 40.
Carmarthen Fans, 39, 50.
Carmarthenshire, 34.
Carn Bica, 53.
Carn Menelez, 22–24.
Carn Mosyn, 50.
Carrickmines, 191.
Catalogue of Types and Figured Specimens, 200, 204.
Cefn-y-Bryn, 40.
Cennen, 38, 39, 50, 51.
Cerig Gwynion Grits, 61
Champernowne, A., 28.
Chard, 58.
Chelius, C., 71.




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Chellaston, 8, 9.
Chert, 40, 42, 92, 146, 149.
Cheshire, 5, 8, 10, 15, 16.
China Stone, 26.
Churnet Valley, 13.
Clay-boulders, 191.
Clay, Puddling, 53.
Clayton, E. G., 83.
Clee Hill, 63.
Clints, 125.
Close, Rev. M. H., 185.
Clough, C. T., 92, 95–99, 114, 117, 118, 130, 146, 149, 152, 155, 181.
Coals, Analyses of, 72.
Coal Measures, 42, 63.
Coal-seams, 43 *et seq.*
Cobban, A. McD., 5.
Combe Pyne Hill, 54, 56–59.
Congleton, 10, 11.
Copper-ore, 157.
Cornbrash, 59.
Cornwall, 16.
Craig, E. H. Cunningham, 68, 157, 165–175, 181.
Crampton, Dr. C. B., 95, 96, 104–107, 109, 113, 116, 177, 181.
Cretaceous, 3, 92, 145, 146.
Crewe, 10, 11.
Cribarth, 35.
Crinan, 118.
Crinoidea, 206.
Crowle, 64, 65.
Crowstones, 16.
Crush conglomerates, 17, 129, 130.
Cunningham Craig, E. H., 68, 157, 165–175, 181.
Cuillin Hills, 86, 87.
Cystidea, 204.

## D

Dana, J. D., 90.
Dane Valley, 10–13, 15, 16.
Dartmouth Slates, 27–30.
Deeley, R. M., 9.
De la Beche, Sir H. T., 2, 17, 21, 30, 41, 42, 83.
Derby, 8, 9.
Derbyshire, 5, 8, 9.
Derwent Valley, 9, 10.
Descloiseaux, A., 90.
Devonian, 27 ; fossils, 91, 92.
Devonshire, 16.
*Didymograptus*-shales, 35–37.
Diorite, 98, 125, 164, 165.
Dixon, E. E. L., 20, 23, 25, 58.
Dodder Valley, 187–189, 194, 195.
Doggers, 60.
Dolomite, 84, 131.
Downton, 62.
Downtonian, 178.
Drift deposits. See Glacial.
Drumlins, 186.
Dublin District, 183.
Dunite, 149.
Dust, Wind-borne, 33.
Dyffryn Flags, 60.
Dykes of gravel and clay, 191.
Dykes, Igneous, 98, 121–123, 137, 140, 149–151.

## E

Echinodermata, Palæozoic, 204.
Echinoidea, 211.
Economics, 53, 103, 156.
Edrio-asteroidea, 209.
Elan, 60, 61.
Elles, G. L., 182.
Elvans, 25.
England and Wales, Field-work, 4.
Eocene, 58.
Eolithic Implements, 59.
Epidiorite, 120, 124, 127, 168, 177.
Epworth, 64.
Erewash Valley, 10.
Eskers, 4, 187, 194, 195, 197.
Essexite, 70.

## F

Falar District, succession of schists in, 161.
Falmouth, 33.
——— Series, 17, 18, 34.
Farewell Rock, 42
Faults, 35, 43, 48, 49.
Fannich Forest, 96, 99, 115.
Felsite, 70.
Feochan, 132.
Ffairfach-grit, 35, 36.
Fire-bricks, 53.
Flett, Dr. J. S., 65–71, 81, 84, 85, 88, 89, 101, 102, 108, 109, 121, 141, 168.
Flood-gravels, 195.
Fluvio-glacial deposits, 10.
Frankley, 60, 63.
Forest Marble, 59, 60.
Forsterite, 132.
Fourchite, 70.
Fowey, 27–29.
Fox, H., 17.
Foyaite, 70.

## G

Galena, 99.
Garnbica, 40.
Gawsworth, 13, 14.
Geikie, Sir A., 84, 146, 178.
——— Prof. J., 14.
Gibson, W., 5, 8, 10, 11, 16, 64, 95.

Digitized by Google

Glacial Drift of Derbyshire, 9; of Cheshire, 10; of Ireland, 4, 185-199; of Scotland, 114, 127, 132, 152; of South Wales, 50.
Glamorganshire, 34.
Glan-Morlais, 47.
Glen Cannich, 101.
—— Cona, 120.
—— Creran, 126.
—— Feshie, 157, 165.
—— Finnan, 121.
—— Nevis, 152.
—— Scaddle, 120.
—— Strathfarrar, 101, 103.
—— Urquhart, 101.
Glenasmole, 188, 199.
Glenelg, 3, 96-98, 114.
Glover, M. F., 64.
Gneisses, 67.
Godolphin, 23, 26.
Godrevy, 20, 33.
Golden Grove, 37.
Goodchild, J. G., 182, 183.
Goole and Marshland railway, 64.
Goostrey, 11, 15.
Gorges, Water-cut, 188, 199.
Gorran Haven, 17.
Gotham, 8, 9, 10.
Gower, 2, 38, 39, 41, 42, 44, 48, 49, 52.
Grainger, Canon, 185.
*Grammysia*-beds, 37.
Granite of Cornwall, 2, 20.
———— of Highlands, 3, 68.
———— of Ben Cruachan, 140.
———— of East Ross-shire, 109, 111.
———— of Glen Domhain, 142.
———— of Glenelg-Ratagan, 97.
———— of Inchbae, 106.
———— of Lismore, 140.
———— of Meall Tionnail, 166
———— North of Tilt Valley, 164.
Grant Wilson, J. S., 70, 118-123, 126-130, 149-152, 154-157, 175.
Graptolites, 61, 62.
Great Oolite, 60, 144.
Green Beds, 66-68, 167, 168.
Greenstone, Cornwall, 19, 20.
Green, U., 28.
Grindlestone Edge, 7, 12.
Grovesend Veins, 44, 45.
Gulval Downs, 21, 25.
Gunn, W., 95, 96, 99, 100, 104, 106, 110, 112, 115, 116, 178, 183.
Gwastaden Group, 60, 61.
Gwennap, 23.
Gwinear, 23, 25.
Gypsum, 8, 9.

## H

Hagley, 63.
Haldon, 57.
Halesowen Sandstones, 63.
Harker, A., 86, 87, 118, 131, 132, 139, 146, 147, 151, 183.
Harris, G. F., 83.
Haxey, 64.
Hayle, 19, 20, 25, 33.
——— Sandstone, 2, 17, 19, 20.
Heaton, 6, 7, 12.
Highlands, Scottish, 3, 65, 95, 118, 157.
Hill, J. B., 17, 18, 22-26, 30, 34, 66, 67, 95, 128, 183.
Hinch, Mr., 198.
Hinde, Dr. G. J., 92, 146.
Hind, Dr. Wheelton, 177, 182.
Hinton Sand, 60.
Hinxman, L. W., 58, 66, 67, 86, 95, 96, 100, 101, 102, 111, 115.
Honestones, 159, 160.
Honiton, 58.
Hornblendite, 97, 109.
Horne, Dr. J., 1, 95, 96, 99, 100, 115, 157.
Hornfels, 108, 125, 126, 129, 164, 173.
Horton, 6, 7.
Howe, J. A., 5, 8, 11, 12, 15.
Howth, 187, 197, 198.
Hullavington, 59, 60.
Hull, Prof. E., 185.
Hutchings, W. M., 152.

## I

Ice-sheet, 187, 193.
Inchbae, 106.
Inferior Oolite, 143.
Interglacial, 9.
Inverguseran, 98, 114.
Inverlael Forest, 96, 104.
Inverness-shire, 95, 96, 101, 112, 115, 149.
Ireland, Field-work in, 183.

## J

Jarrowite, 89, 90.
Joints, 125.
Judd, Prof. J. W., 109.
Jukes-Browne, A. J., 5.
Jurassic, 8, 9, 92, 142-145.

## K

Kames, 116, 187.
Kea, 25.
Kelly, J., 185.
Kennal Vale, 24.
Kentallenite, 141.
Kersantite, 69.
Keuper, 54, 64.

Digitized by Google

Kidston, R., 177–180.
Kilbride, 124.
Kildermorie, 108.
Kill of the Grange, 191, 193, 194.
Killas, 19, 21, 22, 25.
Killiecrankie, 173.
Killiney, 191–194.
Kilmartin District, 126; Physical Features of, 127; Succession of metamorphic rocks in, 128; Glacial phenomena of, 154, 156.
Kilmore, 153.
Kilroe, J. R., 183, 184, 189–194.
Kimeridgian, 145.
Kinahan, G. H., 185.
Kincardine, 110, 117.
Kingsbridge, 28.
Kingshouse, 137.
Kingswear, 27.
Kitchen-midden, 198.
Kitchin, Dr. F. L., 91, 145.
Knapdale, 118.
Knighton, 62.
Knoll-structure, 186.
Kynaston, H., 67, 118, 123–126, 134–140, 183.

## L

Laccolite, of Ben Vrackie, 172, 173.
Lacustrine clay, 10, 14.
Lamplugh, G. W., 1, 5, 91, 183–189, 197.
Lamprophyres, 69, 70, 98, 101, 102, 137, 141, 165.
Land's End, 2, 18, 19, 20, 21, 26, 33.
Landslips, 54, 55.
Lapworth, Prof. C., 182.
———, H., 60, 61.
Lask Edge, 6.
Lee, 6, 7.
Lelant, 19, 33.
Levant Mine, 22.
Lewisian, 96, 97, 99.
Lias, 8, 9, 92, 142.
Library, 94.
Liffey, 186, 187, 188, 189, 194–196.
Lime, 53, 125, 156.
Limestone-breccia, 141.
Lismore, 124, 153, 155.
Lizard, 18.
Llandilo, 35, 36.
——— Beds, 35, 36, 37.
Llandovery Beds, 60, 61.
Llan-Elen Sandstones, 48.
Llanelly, 42, 44, 45, 52.
Llanvirn Beds, 35.
Lletty Grit, 37.
Loch Awe, 66, 67, 124.
—— Bracadale, 147.
—— Brittle, 147.
—— Eil, 118, 119.
—— Linnhe, 118, 123.
Loch Scamadale, 124, 134, 136.
—— Sheil, 118.
—— Staffin series, 144.
Lodes, 25.
Logan, Sir W. E., 42.
Loughor, 44, 45, 47, 51.
Looe, 28, 29, 91, 92.
Lorne, 118, 132, 155.
Lower Compton, 31.
Lower Lias, 8, 9, 92, 142.
——— Limestone Shales, 40.
Ludlow Beds, 37, 40, 62.
Lyme Regis, 58, 59; Railway, 53.

## M

Macaulay, F. W., 63.
Macclesfield, 10, 12, 13.
Macconochie, A., 177, 178, 181.
McHenry, A., 183, 184, 194–196.
McKie, J., 62.
Magnesian Limestone, Weathering of, 83.
Maiden Newton, 58.
Malachite, 157.
Malchite, 3, 70, 121, 123.
Manganese, 157.
Mansergh, J., 5.
Maps, England and Wales, 4, 94; Scotland, 183; Ireland, 199.
——, Six-inch Reference, England and Wales, 94.
Marr, J. E., 36.
Meadfoot Beds, 28, 29.
Meall Uaine, 170.
Memoirs, England and Wales, 4, 95.
Metalliferous veins, 25.
Metamorphic Rocks, 96, 118, 137.
Metamorphism, 66, 67, 108, 125, 126, 131, 139, 141, 163, 167; around Cornish granite, 20, 22, 23.
Mewslade Bay, 50.
Mica-trap, 98, 101, 111.
Mickleover, 9.
Middle Glacial, 191.
Middlewich, 10.
Miers, Prof. H. A., 90.
Miller, H., 109.
Millstone Grit, 6, 42.
Minerals from Skye and Ross-shire, 86.
Mineral veins, 25.
Minette, 69.
Mining information, 2.
Moine Schists, 96, 97, 98, 100, 101, 104, 105, 110, 120, 157, 165, 166.
Monchiquite, 69.
Monckton, H. W., 5, 92.
Montpelier Hill, 188, 199.
Mounts Bay, 32.
Muff, H. B., 118, 124, 126–130, 140, 149–151, 153–156.
Mullion Island, 17, 18.

Digitized by Google

Mumbles Head Beds, 41.
Museum, Edinburgh, 182.
——— of Practical Geology, 91–94, 200.
Mylor Series, 17, 18, 19, 20, 34.

N

Nare Point, 17, 18.
Neath, 45, 46.
Newlyn, 19, 32, 88.
Newton, E. T., 91–93, 95, 145, 146, 149, 181, 183.
Newton Abbot, 57.
——— Nottage, 41.
Newtonmore, 166.
Norham Bridge, 179.

O

Oban, 153.
Odenwald, 3.
Old Hill Marls, 63.
Old Red Sandstone, 37, 38, 62, 111–114, 132.
Ophicalcites, 132.
Ophiuroidea, 210.
Ordovician, 16, 34, 37, 61.
Osann, A, 71.
*Ostrea Sowerbyi*, 59, 60.
Over-thrusts, 34.
Oxfordian, 144.
Oxwich Head, 41.
——— Point, 50.
Oystermouth, 41.

P

Paignton, 28.
Paint-manufacture, 49, 53.
Palæontological Work, 91, 177.
Passage Beds, 37, 38, 39.
Paton, J., 90.
Peach, B. N., 118, 124, 126–130, 132–134, 142, 149–151, 153–156, 177, 179, 181–183.
Peat, 16, 65, 99, 103, 127, 133, 147, 155, 157.
Pegmatite, 86, 97, 101, 105, 107, 120, 122.
Pencarrow Head, 29, 30.
Pencatite, 132.
Penlee, 32.
Pennant Series, 44.
Pennine Hills, 12, 15.
Penryn, 25.
——— granite, 23.
Penybont Tunnel, 61, 62.
Penzance, 19, 21, 32, 33.
Peover, 11, 15.
Peridotite, 149.
Permian, 7, 8, 63, 64.
Perthshire, 157, 167, 168–177.
Petrographical Work, 65.
Phillack, 19, 20.
Phillips, R., 83.
Phœnix Park, 197.
Phyllite, 128, 129.
Phyllocarida, Fossil, 200.
Picotite, 86.
Picrite, 149.
Pitlochry and Blair Atholl District, succession of Schists in, 172.
Plants from Reading Beds, 92.
Pleistocene (Derbyshire), 9; (Cheshire), 10. See also Glacial Drift.
Plinthite, 148.
Pliocene, 31.
Plymouth, 29, 30.
Pocock, T. I., 5, 12–15.
Pollard, Dr. W., 56, 71–91.
Polperro, 27, 29.
Porphyrite, 98, 137, 140.
Port Eynon, 49, 53.
Portscatho Series, 17, 18, 34.
Portland Stone, 83.
Post Glacial, 117.
Pottery, Collection of, 93.
Praeger, R. Ll., 185, 191.
Pseudogaylussite, 89.
Publications, England and Wales, 94; Scotland, 183; Ireland, 199.
Pyroxenite, 97.

Q

Quartz-felsite, 98.
Quartz-porphyry, 166.
Quartzite, Central Highlands, 162, 169, 171, 172, 176.
Quethiock, 27.

R

Radiolarian beds, 17, 42.
Radley, E. G., 71.
Railway-cuttings, 5, 53, 121, 122.
Raised Beaches 32, 49, 117, 195, 198.
Rathfarnham, 187, 194.
Reade, T. M., 185.
Reading Beds, 92.
Recent Deposits, 15.
Reedness, 65.
Reid, C., 4, 10, 16–26, 31–34, 57, 58, 88.
Renwick, 90.
Rhætic Beds, 8, 9, 55.
Rhayader, 60, 61.
Rhossili Bay, 52.
Ringmore, 29.

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River gravels, 9.
Road-metal, 16, 156.
Roberts, G. E., 63.
——— T., 36.
Rosenbusch, Prof. H., 70, 71.
Ross-shire, 95, 96, 100, 102, 104, 115.
Rottenstone, 36, 40, 41, 80.
Rudler, F. W., 90, 93, 94.
Rudyard, 6, 7.
Rushton, 1, 6–8.
——— Spencer, 5.

## S

St. Erth, 19, 31.
St. Ives Bay, 18, 33.
Sandbach, 10, 11.
Sand, Combe Pyne, Composition of, 56.
Salt-regions, 16.
Scalpay, 145.
Schists, 67.
Sconser, 142.
Scotland, Field-work in, 95.
Scottish Highlands, 65, 95, 118, 157.
Scyelite, 106, 109.
Sections published, England and Wales, 94.
Senni Beds, 39.
Seward, A. C., 181.
Seyler, C. A., 72.
Seymour, H. J., 102, 183, 184, 196, 197.
Shelly drift, 187, 192, 193, 197.
Siddington, 14.
Silica sand, 41.
Sills, 147, 148, 172–174.
Silurian, 16, 35, 36, 60.
Sinfin Moor, 10.
Sketty, 51, 52.
Skye, 86, 87, 92, 118, 131, 132, 142–149.
Smith, C. H., 83.
Smith, Wm., 60, 83.
Soay, 3, 130, 149, 152, 155.
Soils, 16, 33, 53, 98, 103, 127, 132, 147, 148, 193, 194.
Sollas, Prof. W. J., 185.
Southern Uplands, 65, 66.
South Wales Coals, 72.
———— Direct Railway, 59.
———— District, 34.
———— Rottenstone, 80.
Spangle schists, 107.
Spessartite, 69, 70.
*Spirorbis*-limestone, 64.
Staddon grits, 29, 30.
Staffordshire, 5, 8.
Stourbridge, 63.
Strahan, A., 4, 32, 34, 35, 38–40, 44–53, 59, 72, 95.
Strangways, C. Fox, 4, 5, 8–10.
Strathaird, 142.
Strathglass, 101, 102, 103.
Strathrusdale, 96, 106, 116.
Strath Tummel, 175.
Strathvaich, 96, 105, 112, 116.
Strollamus, 142, 143, 144.
Struan, 160.
Struy, 101.
Suishnish, Skye, 92.
Sulphur well, 99.
Sutherlandshire, 95.
Swansea, 42, 44, 45, 47, 51, 52.
Syenite, 97.
Symes, R. G., 136, 142, 150, 151.

## T

Tait, D., 131, 143, 177, 178, 181.
Tarannon Beds, 61.
Tarf, 157.
Tawney, E. B., 49.
Taynuilt, 134.
Teall, J. J. H., 1–4, 30, 70, 129, 131, 132, 164.
Terraces of gravel, 9, 10, 13, 15.
Tertiary, 31, 56; igneous rocks, 87, 114, 147–152.
Theralite, 70.
Thomas, H. H., 34–39, 56, 57.
Ticknock Valley, 196.
Tiddeman, R. H., 34, 38–42, 52, 95.
Tilestones, 37, 38, 53.
Tilt, 159.
Titterstone Clee Hill, 62.
Tolka river, 198.
Tonalite, 141.
Torquay, 28, 91, 92.
Torridonian, 130–131.
Towy Valley, 50.
Trapp, 38, 39.
Traquair, Dr. R. H., 177, 181, 182.
Trechmann, Dr. C. O., 89–91.
Tregantle, 29.
Treluswell, 24.
Tremolite limestone, 158, 161, 170, 172.
Trent Valley, 8, 9, 10.
Trias, 8, 49, 54, 63, 64, 142.
Trichrug, 36,
———— Beds, 37.
Trimpley, 63.
Troctolite, 149, 152.
Truro, 25.
Tuedian, 179.
Type Specimens, Catalogue of, 200, 204.

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U

Uplyme, 58.
Upper Greensand, 55, 56, 58, 59.
Upper Lias, 143.
Upper and Lower Boulder Clay, 191, 193.
Ussher, W. A. E., 27–31, 58, 91, 92, 95.

V

Vale of Neath, 35.
Valley gravels, 9, 54.
Veryan Beds, 17, 18.
Vogesite, 69, 141.
Volcanic rocks of Blackmount, 137; of Lorne, 132; of Skye, 87, 147.

W

Wales, South, District, 34.
Warmingham Moss, 16.
Water Supply, 16, 32, 103, 125.
Watts, Prof. W. W., 61.
Wavellite, 42.
Wearde Beds, 2.
—— Efford, 31.
Weathering of Magnesian Limestone, 83.
Weaver Valley, 11.
Wedd, C. B., 5–8, 11, 12, 15, 95, 118, 131, 142–146.
Welsh Moor, 52.
Wenlock Beds, 37, 61.
Wheelock, 11.
Whidborne, Rev. G. F., 28.
Whitaker, W., 59.
Whiteadder, 179–181.
Whitesand Bay, 25.
Wilkinson, B. S. N., 34, 39, 40, 49, 50, 52, 53.
Williams, G. H., 90.
Wilson, J. S. G., 70, 118–123, 126–130, 149–152, 154–157, 175.
Wood, E. M. R., 61, 182.
Woodward, H. B., 1, 4, 5, 53–60, 95.
Wootton Bassett, 59.
Worms Head, 50.
Wright, W. B., 183, 184, 196–199.
Wyre Forest, 62, 63.

Y

Yarcombe, 58.
Yoredale Sandstones, 6.

Z

Zennor, 21.
Zoisite-schist, 121.


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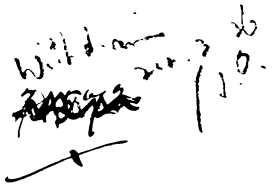

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# CONTENTS.


PAGE.

INTRODUCTION BY THE DIRECTOR .. . . ... ... .. 1

I. ENGLAND AND WALES.

I. FIELD-WORK ... ... ... ... ... ... ... ... 6
1. Midland District ... ... ... ... ... ... 8
2. London District ... ... ... ... ... ... ... 24
3. Southern District .. ... ... ... ... ... ... 25
4. South Wales District .. ... ... ... ... .. 40

II. PETROGRAPHICAL WORK ... ... . . .. ... . . 53

III. CHEMICAL WORK ... ... ... ... ... ... ... 56

IV. PALÆONTOLOGICAL WORK ... ... ... ... ... ... 61
List of Specimens in Museum recently figured ... ... 63

V. MUSEUM OF PRACTICAL GEOLOGY ... ... ... ... . 64

II. SCOTLAND.

I. FIELD-WORK ... ... ... ... ... .. ... ... 64
1. Argyllshire—Knapdale, Lorne, and northwards to Loch Sheil ... ... ... .. ... ... ... ... 65
2. Central and Eastern Ross, with parts of Inverness-shire and Sutherlandshire .. ... .. .. ... ... 84
3. East Highland District ... ... ... ... ... .. 93
4. Rum, Eigg, and part of Mull ... ... ... ... ... 106
5. Revision of Carboniferous Areas ... ... ... ... 115
A. Midlothian, parts of West and East Lothian, and Peebles-shire ... ... ... ... ... ... 115
B. Prestonpans to Cockburnspath ... ... ... ... 120

II. PALÆONTOLOGICAL WORK .. ... ... .. .. ... 129

III. MUSEUM WORK ... ... ... . . ... ... ... ... 138

III. IRELAND.

FIELD-WORK ... ... ... . . .. . . ... ... 138
Belfast District ... ... .. ... ... ... .. 138

V. MAPS AND MEMOIRS PREPARED AND PUBLISHED ... 148

APPENDIX : I. On the Development of Crystalline Schists from Granite and Hornfels in Zones of Secondary Shearing. By C. T. CLOUGH, M.A. ... ... ... 150

" II. Note on some Brecciated Stanniferous Veinstones from Cornwall. By J. S. FLETT, M.A., D.Sc. ... 154

" III. Remarks on the Devonian and Carboniferous Rocks in South Devon and Cornwall. By W. A. E. USSHER, F.G.S. ... ... ... .. .. 160



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APPENDIX—*continued.* PAGE.

,, IV. The Coal-measures of Llanelly, Llannon, and Cross Hands in the South Wales Coal-Field. By A. STRAHAN, M.A., F.G.S., T. C. CANTRILL, B.Sc., and E. E. L. DIXON, B.Sc. ... ... ... ... 170

,, V. Cutting on the South Wales Direct Railway, near Chipping Sodbury. By A. STRAHAN, M.A., F.G.S. 192

,, VI. The Woodford and Ilford Railway. By J. ALLEN HOWE, B.Sc., F.G.S. ... ... ... ... 194

,, VII. Notes on the Occurrence of Natural Gas at Heathfield, Sussex. By H. B. WOODWARD, F.R.S. ... 195

,, VIII. On the Drifts of the Thames Valley near London. By T. I. POCOCK, M.A. ... ... ... ... 199

,, IX. Note on the Palæolithic Gravel of Savernake Forest, Wiltshire. By C. REID, F.R.S. ... ... ... 207

,, X. The Fossil Plants from the Canonbie Coal Field. By R. KIDSTON, F.R.S. ... ... ... ... ... 209

,, XI. Catalogue of Types and Figured Specimens of British Gasteropoda and Scaphopoda from the Rhætic Beds, Lias, and Inferior Oolite, preserved in the Museum of Practical Geology. By H. A. ALLEN, F.G.S. ... ... ... ... ... ... ... 217

INDEX ... ... ... .. ... ... .. . ... ... .. 228

## ILLUSTRATIONS.

FIG 1.—Section of lodes in the Camborne Area .. ... ... .. 39

,, 2.—Overthrust in Caswell Bay ... ... ... .. ... ... 48

,, 3.—Islands off the coast of Lorn ... ... ... ... ... ... 69

,, 4.—Terraces of Glacial Lake, Strath Tay ... ... ... ... 105

,, 5.—Index to Belfast Sheet... ... ... ... ... ... .. 139

,, 6.—Map of country near Cnoc an t'Saic, S.W. of Bonar Bridge ... 152

,, 7.—Diagram Section of vertical thrust in Garbh Allt... ... ... 153

,, 8.—Section across the Llanelly Syncline ... ... ... .. 176

,, 9.—Railway-cutting near Chipping Sodbury ... ... ... ... 192

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# SUMMARY OF PROGRESS

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## *INTRODUCTION.*

BY J J. H. TEALL, M.A., F.R.S., DIRECTOR.

In England and Wales field work has been carried on in four areas, Devon and Cornwall, South Wales, the Midlands and the London District. In Scotland the work has been distributed over six districts, four of which are situated in the unsurveyed portion of the Highlands and two in the Carboniferous areas of the Midland Valley. In Ireland the Drift Survey was continued in the neighbourhood of Belfast. A few of the more important features of the work of the year will now be briefly referred to.

**Highland Metamorphic rocks.**

In all probability the oldest rocks with which the Survey has had to deal in the course of the year occur in the Highland Metamorphic region. Previous work in the areas occupied by the Eastern Highland Schists in the north of Scotland have demonstrated the existence of extensive tracts of country composed of rocks closely resembling certain portions of Lewisian gneiss, especially those which occur in zones of secondary shearing. Those varieties of gneiss to which reference is here made consist of alternations of acid and basic material, with occasional lenticles of ultra-basic rock; but they differ from the unmodified gneisses in possessing a granulitic structure. Two belts composed of rocks of this type have been met with by Mr. Hinxman in Strathconon Forest, Ross-shire, where they are seen to be most intimately interfolded with siliceous granulites of the Moine type. Although the exact meaning of these facts is not apparent, it may safely be predicted that they will be found to have a most important bearing on the origin of the Eastern Highland Schists of Sutherland and Ross.

Other facts, which are also of importance from the same point of view, have been observed by Mr. Clough in central Ross-shire. A granitic rock has, at some early period, been intruded into sediments which have been converted into hornfels by contact action. Zones of thrusting and shearing, comparable to those which have been described in the Lewisian gneiss, traverse both



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Highland Metamorphic rocks.

the granitic area and that occupied by the altered sediments, with the result that the hornfels has been "converted into mica-schists, and the granitic rocks into finely foliated augen-gneisses, with a granulitic matrix."

In the southern Highlands Dr. Peach and the officers acting under his direction have made important observations on the mainland and in the islands which form the western part of Argyllshire. The great quartzite formation of Islay and Jura, which has been split up into several recognisable zones, in some of which flattened worm casts (fucoids) occur, has been followed into Scarba, and evidence has been obtained that the boulder beds which are so well developed in the Isles of the Sea form the natural base of this group of strata. These beds contain fragments, many of which are rounded, of the underlying Degnish and Shuna limestones.

In the eastern Highland district much attention has been paid to the characters and relative ages of the complex igneous intrusions, but the different observers have not yet reached perfect agreement on this subject. Special interest attaches to this region, because the banded granulitic schists and gneisses of Moine type are here brought into relation with the quartzites, black schists and limestones of the Perthshire series. Mr. Barrow brings forward evidence to show that schists of Moine type occur between the quartzite and a persistent band which he calls the "little limestone."

Torridonian.

The Torridonian rocks may next be referred to, but it must be understood that taking them in this order is in no way intended to prejudice the question as to whether rocks of this, or even later age, may not enter into the composition of the Eastern Highland Schists. Mr. Harker describes these rocks as they are developed in Rum, and shows that they have been affected by the post-Cambrian thrust movements. In the north-west of the Island a prominent crush breccia, composed of lenticles of Cambrian limestone and crushed sandstone, overlies the thrust-plane.

Lower Palæozoic.

The detailed mapping of the Lower Palæozoic rocks on the north side of the Carboniferous area in South Wales has shown that the anticline in which the oldest rocks come to the surface follows the Towy Valley, and Messrs. Cantrill and Thomas have recognised an inversion which has had the effect of bringing *Didymograptus-bifidus* shales over Llandeilo beds.

Old Red Sandstone and Devonian.

Additional evidence of the fact that the lavas of the Lorne plateau were poured out on an uneven surface formed of the Highland schists has been obtained in the course of mapping the southern margin of this plateau to the north of Loch Melfort, and definite proof of the Lower Old Red Sandstone age of the Glencoe volcanic rocks has been furnished by the discovery of *Psilophyton* in shales which are associated with the lavas.

In England the Old Red Sandstone Rocks on the borders of the South Wales coal-field have been examined, and evidence of a powerful strike fault, or rather series of faults, traversing the central portion of the northern band has been obtained. "The course of this disturbance," as Mr. Strahan says, "along the middle

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of the outcrop of the Old Red Sandstone for so many miles, its effect in throwing in patches of Carboniferous limestone by what must be an enormous displacement, and lastly, the guiding influence which it has exerted upon the rivers, in common with other disturbances, of the east-north-east and west-south-west system, all combine to give it an unusual interest." Old Red Sandstone and Devonian.

In North Cornwall the purple and green slates with *Pteraspis* which occur in Watergate Bay have engaged the attention of Mr. Reid. They are of special interest as indicating both by their fossil contents and lithological characters the existence of the Old Red Sandstone facies within the Devonian area. They are succeeded towards the south by more or less calcareous beds containing marine fossils apparently of Lower Devonian age; but these fossiliferous rocks have not as yet been traced into connection with the Mylor, Falmouth and Portscatho groups, in which no fossils have as yet been found. The Hayle sandstone, which was referred to in last year's Summary as a new group, turns out to be merely a portion of the Portscatho series.

Reference may here be made to the mining and petrological work which has been carried on in the west of England. Mr. MacAlister has examined a very large number of mining plans and reduced the observations to twenty-five inch maps, from which they will be still further reduced to the six inch and one inch maps on which the geological information is recorded. This work has supplied the Geological Survey with a large amount of information as to the form of the underground surface of the granite, the distribution of the more valuable "bunches" of ore in the lodes, the courses of the lodes and their relation to the granite and killas. Some particulars of this work will be found in the following pages, but the full discussion of the many interesting problems connected with the lodes is necessarily deferred until the surface mapping of the mineral regions is further advanced.

If we except the important paper by Mr. J. H. Collins, "On some Cornish tin-stones and tin-capels," but little work has been done on the microscopic structure of the vein-stones. Dr. Flett's report on material collected from various lodes by Mr. Scrivenor and Mr. MacAlister is therefore of special interest. In it he shows that the vein-stones have a complex history, which is recorded in their microscopic structure. Brecciation and infiltration have succeeded each other again and again, and the infiltrated material has varied in composition from time to time.

Intimately connected with the genesis of the ore-deposits is the conversion of granite into greisen by pneumatolytic action, proceeding outwards from joint planes. A very interesting illustration of this process occurs at Cligga Head, where it has been studied in detail by Mr. Scrivenor, who gives the result of his work in the present Summary.

The work of mapping the coal-fields of England on the six-inch scale has been continued in South Wales and in the Carboniferous.



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Carboniferous.

Midland Counties, while in Scotland the work of revising the old six-inch maps has commenced. In South Wales the mapping of the coal-field proceeds steadily towards the west, and much information as to the correlation of the coal-seams and the nature of the disturbances will be found in the following pages. Three systems of faulting or folding exist. The steep uplift which determines the southern margin of the coal-basin and the Llanelly syncline belong to the pre-Triassic system, which traverses the vale of Glamorgan. A long series of north-north-west faults, the course of which across the pre-Triassic folds has been worked out in detail, belongs to the system which is certainly in part of post-Triassic, but probably in part also of pre-Triassic age. Lastly, a series of parallel disturbances of great magnitude, which traverse the northern part of the coal-field, the Old Red Sandstone and the Lower Palæozoic rocks, and which have determined the river drainage, may be assigned to the system of which the Neath disturbance is a well-known example. This third system, which is characterised by folding and overthrusting on a large scale, runs in a general west-south-west direction, and from its remarkable influence on the surface configuration is believed to be of later date than the others.

In the Midland District the work has been confined to the southern and western part of the Derbyshire and Nottinghamshire coal-field. Mr. Wedd has mapped out the various beds of Millstone Grit which were not separated in the original Survey, and one result of his work has been to relegate a considerable tract of country which was formerly regarded as Coal Measures to the Millstone Grit formation. Mr. Gibson has continued his researches on the higher measures of this coal-field, and has obtained additional evidence to prove that beds above the Top Hard which have been brought to light in the Gedling shafts and in the Thurgarton boring are palæontologically, lithologically and stratigraphically comparable with the higher measures occurring in other Midland coal-fields. As he points out, there seems no escape from the conclusion that the Pennine elevation, with the consequent breaking up of the syncline, was subsequent to their deposition. He has also obtained evidence of the existence of marine conditions during the deposition of the Coal Measures at several horizons, both low down and high up in the series, and in view of these facts he naturally asks whether a much larger portion of our Coal Measures has not been formed under marine conditions than is generally supposed. In working out the palæontology of the Coal Measures, Mr. Gibson has received valuable aid from Dr. Wheelton Hind, whose name frequently recurs in the following pages.

In Scotland the revision of the Carboniferous areas has been commenced in the eastern part of the Midland Valley. Mr. Wilson has re-examined the oil-shale field to the west of Edinburgh, and calls attention, in his report, to the fact that the shales in that region, with few exceptions, deteriorate both in the quantity and quality of the oil as they are followed downwards. If this should prove to be a general law, it will obviously

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Carboniferous.

have a very important bearing on estimates of the value of any area in which the oil-shale horizons exist, and raise an interesting problem as to the nature of the processes by which the oil-producing compounds have been concentrated near the existing surface.

The examination of the coast between Dunbar and Cockburnspath has enabled Mr. Clough to prepare a detailed section of the Carboniferous limestone series, and to show that the beds which dip under the sea along a portion of the coast are probably very near the base of the Edge coals of Midlothian. These coals may therefore exist beneath the sea under conditions which will enable them to be worked at some future time.

But the most striking addition to our knowledge of the Carboniferous rocks of Scotland, is that furnished by Mr. Kidston's examination of a large suite of plants from the Canonbie Coal-field, in the collection of which he was assisted by Mr. Macconochie. This proves that upper, middle, and lower Coal-measures are here present. According to Mr. Kidston, the highest measures are on the horizon of the Radstock beds; an horizon which is higher than any reached in the midland or northern coal-fields so far as is at present known.

Permian and Trias.

A few facts with regard to the Permian and Trias are recorded in that portion of the Summary which deals with the Midland area; but the work of mapping these rocks over the concealed part of the Nottinghamshire Coal-field has not yet commenced. This work will be of considerable importance with reference to the future development of the coal-field, because it is certain that some of the faults which affect the Permian and Trias are due to the comparatively slight movement along important pre-Triassic dislocations. As the work of developing the coal-field proceeds, it may be possible, from a study of the faults in the red rocks and in the Coal Measures, to locate with approximate accuracy the more important faults in the remaining portions of the concealed basin. Special attention will therefore be paid to the mapping of the Trias as soon as the exposed part of the coal-basin has been surveyed.

Jurassic

The only district where Jurassic rocks have been met with during the year is in the island of Eigg. Here marine Oxfordian with Cordate Ammonites and representatives of the Great Estuarine Series (Great Oolite) have been mapped. There is a break in the section so that the intervening stata which should consist of the *macrocephalus*-beds are not exposed.

Tertiary.

The work of surveying the Tertiary volcanic regions of the west of Scotland has been continued by Mr. Harker, who devoted his attention in 1902 to the Isle of Rum. The most interesting feature of the work in this region is the recognition of lenticular masses and patches of gneiss, usually of acid composition, but partly also of basic and composite character, These are intruded

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into the Torridonian rocks which show signs of contact alteration. Their injection is evidently later than the post-Cambrian movements and is referred by Mr. Harker to the Tertiary period.

Pleistocene and recent.

In all areas where the work of the Survey has been going on observations have been made upon the Pleistocene and recent deposits. It is difficult to select points for special reference. Attention may, however, be directed to the work in the Belfast area, where Mr. Lamplugh and his colleagues have been occupied exclusively with the drifts, to the glacial lakes of the Tay and the Tummel described by Mr. Wilson, and to the existence of an area in the Central Highlands, where little or no glacial erosion has taken place, to which Mr. Barrow and Mr. Craig refer.

# I.—ENGLAND AND WALES.

## I.—FIELD-WORK.

Mr. Woodward.

The ground to be surveyed was arranged in four areas, one under Mr. H. B. Woodward, and three under the District Geologists, as follows:—

1. Midland district under Mr. C. Fox-Strangways.
2. London district under Mr. Woodward, F.R.S.
3. Southern district under Mr. Clement Reid, F.R.S.
4. South Wales district under Mr. A. Strahan, M.A.

In the *Midland district* work was commenced along the southern borders of the Derbyshire and Nottinghamshire coal-fields in sheet 125 (Derby). The district memoir on the North Staffordshire coal-fields, and the memoir on sheet 141 (the Geology of the country between Derby and Loughborough), have been completed; those on sheet 156 (the Geology of the country near Leicester) and on the Cheadle coal-field are nearly ready for publication; while the district memoirs on the Leicestershire coal-field, the memoir on sheet 110 (the Geology of the country around Congleton, Macclesfield, etc.), and a new edition of that on sheet 54 (the Geology of the Oolitic and Cretaceous rocks south of Scarborough) are in preparation.

The first one-inch colour-printed map, that of sheet 123 (Stoke-upon-Trent) has been prepared at the Ordnance Survey Office, and issued in two editions, with and without drift.

In the *London district* those portions of the Thames Valley in which the brickearths and gravels had not previously been surveyed in detail on the six-inch scale have now been mapped. A special one-inch map in four sheets, with London in the centre, has been prepared at the Ordnance Survey Office, and steps are now being taken to publish these with the geological information printed in colours.

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In the *Southern district* progress has been made in the survey of sheets 346 (Newquay), 347 (Lostwithiel), and 352 (Falmouth and Truro). Mining information has been obtained in the chief metalliferous district of Redruth and Camborne, and some particulars of the mines in the Lands End district have also been obtained. Mr. Woodward.

The memoir on sheet 350 (the Geology of the country around Torquay) has been completed; that on sheets 355 and 356 (the Geology of the country around Kingsbridge and Salcombe) is nearly completed, and that on sheet 349 (the Geology of the country east of Plymouth) is in hand.

An index to De la Beche's Report on the Geology of Cornwall, Devon, and West Somerset, has been printed, and will shortly be issued.*

Memoirs on sheet 298* (the country around Salisbury), and on sheet 317 (the country around Chichester) are nearly ready for publication; while another on sheet 268 (the country around Reading) is well advanced.

A colour-printed map, sheet 314 (Ringwood) has been issued.

In the *South Wales district* the survey of sheets 230 (Ammanford or Cross Inn) and 246 (Worms Head) has been completed, and work has been carried on in sheet 229 (Carmarthen and Kidwelly). Samples of coal for analysis were collected in various localities between Pontypool and Swansea.

A colour-printed map of the neighbourhood of Cardiff, to replace the hand-coloured map, is in preparation at the Ordnance Survey Office.

The memoir on sheet 248 (on the country around Pontypridd), is nearly ready for publication, and those on sheets 231 (the country around Merthyr Tydvil) and sheets 261 and 262 (the country around Bridgend) are in preparation.

The general memoir on the Cretaceous Rocks of Britain, vol. ii., is nearly ready for publication, while vol. iii. is well advanced. The memoir on the Geology of the Isle of Man is nearly ready for publication.*

Examinations have been made of new railway cuttings between Trowell and Clay Cross in Derbyshire; near Chipping Sodbury in Gloucestershire; from Grateley to Amesbury, near Salisbury; from Uxbridge to Beaconsfield, and near Wembley Park; at Chiselhurst, and from Woodford to Ilford, in Essex.

The sites of the borings for natural gas at Heathfield in Sussex have been visited, by permission of the engineer, Mr. Inverness Watts. Samples obtained from a boring for the Wrexham Waterworks Company have been inspected on the spot, by permission of the engineer, Mr. F. Storr; and a visit has been paid to the site of a boring at Goodwood.

Examination has also been made of sections whence important discoveries of palæolithic implements have been made near Ipswich and near Savernake.

* The Memoirs above noted have since been published.

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## I. Midland District—Derbyshire and Nottinghamshire.

Mr. C. Fox-Strangways, District Geologist.

Mr. W. Gibson, B.Sc.
Mr. C. B. Wedd, B.A. } Geologists.

### CARBONIFEROUS.

Mr. Fox-Strangways and Mr. Gibson.

The fieldwork during the year may be briefly summarised under two heads. Firstly, a start has been made in unravelling the sequence and arrangement of the rocks on the southern and western sides of the Derbyshire coalfield; secondly, on the eastern side much information has been obtained on the important question of the character of the rocks underlying the Triassic formation; while, in addition advantage was taken of the widening of the Midland Railway, between Trowell and Clay Cross to examine the excellent sections of Coal Measures exposed in these cuttings.

In the western part of this district the general dip of the strata is easterly; but at the southern end the beds turn up and dip to the north. The main folds of the strata, as well as the principal faults also follow these directions; the majority of the faults running in a north-west and south-east direction, but curving round to the south, and joining a series of dislocations that run more nearly east and west. These latter frequently bound the Triassic rocks along the southern margin of the coalfield; and although there is evidently much disturbance along this line, it is probable that the junction between the two formations is often unconformable, and that in many cases the Trias is banked against the older rocks.

Mr. Wedd.

The anticlinal uplift shown by the inlier of Carboniferous Limestone at Crich, in the extreme north of this ground, may be regarded as the key to the structure of the neighbourhood. Its influence is shown eastward and south-eastward to Oakerthorpe and Pentrich, as far as the ground has been mapped in these directions, by the concentric curves of increasing radius into which the successive outcrops of the highest beds of Millstone Grit and Coal-measure sandstone are thrown. Its influence, diminishing southward, can be traced in that direction as far as Belper; where, as farther north, the Millstone Grits east of the Derwent Valley are gently upheaved into a low saddle; the complement of which is probably a shallow trough under and west of the river valley. North of Ambergate the eastern limb of the anticline has a steep easterly dip from Bullbridge to east of Crich; while the Kinderscout Grit of the western limb has a gentler westerly dip.

Along a north-westerly line through Lower Hartshay, passing east of Fritchley, the outcrops of the gently-folded strata are seen to form a re-entering angle in this anticlinal uplift, or the termination of a syncline between the eastern and southern parts of it. This line is evidently a line of faulting, probably contemporaneous with the folding.

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Mr. Wedd.

The dip of the Coal Measures from Lower Hartshay southwards to Lower Kilbourne is a gentle one to the east. At Horsley the strike bends round to south-east and east, a change which agrees with the south-westerly prolongation of a shallow syncline proved in the Coal Measures at Denby, and apparently dying out in a south-westerly direction. This syncline which runs in a north-east and south-west direction, is well seen in the sharp bend in the outcrops of the Kinderscout and higher Grits at and north of Little Eaton, and to a greater or less extent in the outcrops of the Coal Measure sandstones. A farther indication of the intimate connexion between faulting and folding is afforded by the fact that the maximum displacement of the strata occurs where the faults cross the trough of the above-mentioned syncline, and that they diminish rapidly towards the anticlinal axis between Crich and Belper. As far as seen, all the faults of the district seem to belong strictly to the local system of folding.

The principal fault, which has been called the Horsley Fault, runs in a north-north-west direction from Morley Moor through Horsley and Lower Kilbourne, passing east and north of Belper. Its general direction is perfectly straight for six miles, but it curves somewhat in crossing alternate hard and soft strata. It has a downthrow to the north-east, the amount of which has not yet been determined; but it diminishes north-west, and possibly dies out north of Belper. From Farlawn, north-east of Belper, to a point west of Kilbourne Station it forms the western boundary of the Coal Measures; but between Holbrook and Horsley, Measures below the Kilburn Coal lie at the surface on the west side of the fault, when it crosses the above-mentioned syncline. The Kilburn Coal is cut out by the fault between Horsley and Mount Pleasant, west of Kilbourne Station. The main fault, or an important part of it, passes between Dobbs Hill Plantation and Horsley Carr to Morley Moor, throwing down higher beds of Millstone Grit against the Kinderscout Grit. Numerous faults, the majority of which have a downthrow to the north-east, run in a general north-westerly direction through Denby and Marehay. The largest downthrow is one of 90 yards to the south-west in a fault proved in the Kilburn Coal west of Denby Church.

In this north-westerly system of faulting, from Wingfield to Breadsall Moor, the prevalent downthrow, at any rate in the numerous small faults, is to the N. E., that is on the side away from the main uplift of the district.

Mr. Gibson.

In the country to the east, the Erewash Valley, which runs nearly in a north and south direction, is excavated on the crest of a gentle anticline bounded on the east and west by a shallow syncline of which the southern rims of each are hidden under the Trias or Alluvial deposits of the Trent. The synclines are crossed by faults having a general north-north-west and south-south-east trend, with a tendency to assume an east-west course on approaching the southern margins of the synclines; but as the examination of the colliery plans has not been completed, the further account of the faulting is deferred.

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*Pendleside Series* (" *Yoredale Rocks*").

Mr. Wedd. Only a very small portion of these rocks has as yet been surveyed; but as far as they have been mapped in the neighbourhood of Hazlewood, Duffield, Quarndon, and Breadsall, the upper part consists of a thick series of shales with occasional thin blue calcareous grits or gritty limestones (*e.g.*, in Depth o' Lumb) and numerous beds of yellow, fine, and rather coarser grained sandstone of no great thickness. Below the lowest of a group of these sandstones at the bridge over the railway cutting (Wirksworth Branch) at Duffield, a few badly preserved *Goniatites* have been found in the shale. A lower part of the series, seen from Cumber-hill, west of Duffield, to Quarndon and Allestree, consists of shales with hard fine-grained white siliceous sandstones, like the crowstones of North Staffordshire, and a few thin grey or blue calcareous sandstones or sandy limestones. *Posidoniella* occurs in this series at two horizons.

*Millstone Grit.*

Apart from the fact that on the published map no attempt was made to differentiate the several beds of Millstone Grit from one another, it has been found necessary in re-surveying this group to depart widely from the original mapping in the district of Ambergate, Belper, Milford and Holbrook. This departure from the former mapping is necessitated, not on account of the choice of a different divisional line between the Coal Measures and Millstone Grit, but because a considerable thickness of strata, rightly assigned to the latter in the north, and also in the south around Coxbench, was erroneously put into the Coal Measures between Holbrook and Ambergate. To this cause is due the disproportionate narrowness of the Millstone Grit outcrop shown at Belper and Milford on the old map, which, without any repetition by faulting or folding, diminishes from a width representing nearly two miles at Coxbench, to a quarter of a mile at Makeney, where the dip is scarcely greater. The Millstone Grits of the district are certainly divisible into four, if not five, different beds in the following descending order.

(*a*) A coarse-grained false-bedded grit with small pebbles, and frequently much pink felspar. This bed is often soft and porous, but sometimes hard and massive. It is white or yellow in colour, but often blotched with red or purple. The thickness probably varies.

Thin shales, generally blue and sandy. There are occasionally indications of a strong bed of gannister at the base of the overlying grit. A thin coal-seam, probably local, occurs below the shales.

(*b*) A thick fine-grained, less false-bedded, more or less micaceous grit, constant in character, and free from pebbles as far north as beyond Belper, where it perhaps becomes somewhat coarser. The colour of the grit is white, and red, or purple; parts of it are often so micaceous as to become shaly in appearance. It is more than 100 feet thick at Coxbench.

Grey shales with thin beds of hard, flaggy sandstone occur at the base.

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(*c*) Fine-grained, white, and red, or purple micaceous grit, similar in appearance to (*b*), but not so thick. This grit occasionally divides into two beds. It has not yet been recognised north of Belper. Mr. Wedd.

Blue shales, in upper part sandy and light-coloured or purple with much mica and obscure plant remains. They are probably quite 100 feet thick at Milford. A seam of coal occurs below.

(*d*) A thick, massive grit consisting of lenticles of false-bedded grit of varying character, mostly coarse-grained and pebbly; white, yellow, or red in colour. Some beds, especially near the bottom, and also not far from the top, are quite conglomeratic, with pebbles occasionally an inch or more in length.

At Stanton by Dale a massive felspathic grit, which was formerly extensively quarried, emerges from beneath the Trias. This rock has been regarded as belonging to the Millstone Grit, but the only evidence for this identification is its resemblance to the Millstone Grit of the western side of the Coalfield, and to the fact of its more massive character than any sandstone in the southern part of the Coal Measures. Mr. Fox-Strangways.

*Coal Measures.*

On the western side of the Coalfield the Measures consist of the usual alternations of sandstones, shales, etc.; but towards the south many of the sandstones in the lower part deteriorate and thin out, or are replaced by others at different horizons, showing a diminution of sandy material in this direction as compared with the neighbourhood of Pentrich and Wingfield in the north. In the Erewash Valley the grey and black shales in the lower part of the Coal Measures contain the "Rakes" or ironstone bands, which formerly furnished the local ore but are now entirely superseded by ores foreign to the Coalfield. Mr. Wedd.

The principal coals now worked on the western margin of the Coalfield are in descending order: The Ell, the Soft, the Deep Hard, the Furnace (Lower Main or Tupton), and the Black Shale or Clod, forming a group at no great distance from each other, and the Kilburn lying at a depth of about 470 feet below the Black Shale Coal.

Below the Kilburn only one or two coals are now worked in the district, and these only at Nether Heage. The principal of these lies almost immediately above the coarse grit (*a*) and is apparently the coal mentioned by Sir Warington Smyth as the Bottom Coal.* It is now worked at Gun Lane Colliery, Nether Heage. This is the same coal as the lower of two seams formerly worked at the old Belperlawn and Nibble-and-Clink Collieries north-east of Belper; at the former, close to the surface, and at the latter at a depth of 45 yards. A level was driven through from one to the other of these collieries in the lower coal, which was a good seam nearly 4 feet thick, being nearly all bright coal. The same coal was lately exposed in the sewage excavations in Stony Lane, on the east side of Holbrook, where it was between 3 and 4 feet thick. Its outcrop can be traced at intervals from

*Mem. Geol. Survey. Iron Ores of Great Britain, Part I. p. 39.

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Mr. Wedd. Ridgeway, near Ambergate, to the south end of Holbrook. Sixteen yards above this coal at Gun Lane is another seam with a roof of pyritous shale, containing numerous badly-preserved *Goniatites*.

The outcrop of the Kilburn Coal can be traced from Buckland Hollow, north of Heage, nearly all the way to Mount Pleasant, west of Kilbourne Station. South of here it is cut out by the Horsley Fault, but reappears again on the east side of the fault, south of Horsley, and is worked from the surface at Horsley Colliery, where a fish-bed with *Megalichthys* lies immediately on the coal, as also at Denby.

Mr. Gibson. Along the southern side of the Coalfield this coal can be traced almost continuously from Morley to Stanton Gate. The different layers composing the coal vary in quality, necessitating hand or mechanical sorting before delivery into the market. A strong rock, occurring at a vertical distance of 70 to 100 yards above the coal, fixes the position of outcrop. This rock frequently assumes a reddish tinge, and is then not unlike the more sandy beds of the Permian. This occasional red colour of these Coal-measure sandstones led to a somewhat higher rock, cropping out at Dale Mill, being regarded as of Permian age, though the field evidence entirely negatives this supposition.

Mr. Wedd. As the condition of deposition of the roof of the coal is of importance in elucidating the mode of formation of coal seams, the following particulars are given :—

*Ell Coal.*—Roof not seen. Shale below the coal contains Entomostraca, *Carbonicola* and fish scales. (Denby).

*Soft Coal.*—Roof dark shale with *Carbonicola*, *Anthracomya* (?), *Spirorbis* and Entomostraca (Salterwood).

*Lower Hard Coal.*—Shale with ironstone nodules and a few *Carbonicola* (Salterwood Colliery).

*Hospital Coal.*—Roof not seen. The coal is associated with strong beds of *Carbonicola* (Denby).

*Furnace Coal.*—Roof two-inches of ironstone, strongly oolitic, except the upper surface which is botryoidal with numerous ferruginous casts of *Carbonicola*, raised markings suggestive of worm-casts, and traces of ferns and wood (Salterwood Colliery and Marehay).

*Blackshale or Clod Coal.*—Roof shale with ironstone nodules containing a few *Calamites* (Heage).

*Kilburn Coal.*—Roof fish-bed with *Megalichthys*, under black shale. (Denby* and Horsley).

*Coal* below the Wingfield Sandstone—Roof not seen.

*Coals* at Ambergate Brickworks—

*Upper Coal* (with gannister floor) : Roof, pyritous shale with numerous *Goniatites*.

*Lower Coal* (?) roof white marl ? not seen.

*Coal* in railway (Ambergate and Pye Bridge Branch) at Sawmill, near Ambergate—Roof shale with ironstone nodules ; no fossils found.

*Upper Coal*, Gun Lane Colliery—Roof pyritous shale with badly preserved *Goniatites*. (Nether Heage).

*Bottom Coal*, Gun Lane Colliery.—Roof strong shale ; no fossils found.

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* At Denby Colliery well preserved plants such as ferns (*Neuropteris*), *Lepidodendron*, and fruit-cones were found in nodules thirty or forty feet below the Black Shale Coal.

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Mr. Gibson.

In the eastern part of the district the ground surveyed during the year did not reach the centre of the syncline or outcrop of the well-known Top Hard Coal; and of the seams between this and the Kilburn Coal but little information has been gathered. The following table will, however, serve to show the distances apart and depth to the more important seams in the Mapperley district.

*Depths to Chief Coals in the Mapperley Colliery.*

| *Name of Seam* | *Depth in yards* |
|---|---|
| Ell Coal | 120 |
| Soft Coal | 125 |
| Deep Hard | 133 |
| Piper Coal | 158 |
| Furnace or Tupton Coal | 196 |
| Blackshale or Clod Coal (Silkstone Coal of Yorkshire) | 248 |
| Cannel Coal | 358 |
| Kilburn Coal | 393 |

From an ironstone band above the Black Shale Coal, Dr. Wheelton Hind, to whom the specimens were sent for identification, recognises *Carbonicola robusta*, *C. turgida*, *C. aquilina*, and *C. nuculuris*.

The associated strata consist, for the most part, of shales, and easily weathered rocks; while those of a more arenaceous character are thin, impersistent, and of a crumbling nature, rendering it impossible to trace their outcrops beyond very limited distances.

On the east side of the Erewash Valley, the strata between Awsworth and the Bramcote Hills dip continuously eastward at about 1 in 10; and, as in the extreme south-western margin the lowest horizon in the disused Stapleford Colliery lies 60 yards above the Kilburn Coal (which, by a series of downthrow faults, is increased to 260 yards in the Cossall Colliery), higher and higher measures continue to be introduced eastward. The result is that the Top Hard Coal crops out to the east of Babbington, though, in a short distance the outcrop disappears under the Magnesian Limestone, and, excepting the small inlier of Broxtowe Wood, and the narrow tongue cut through by the Midland and Great Northern Railways at Kimberley, all information regarding the character of the strata above the Top Hard has to be obtained from the sinking of coal shafts. The opportunity afforded through the courtesy of the owners and managers of the Gedling and Sherwood collieries, of examining, from time to time, the material brought to the surface during the recent new sinkings, was therefore taken advantage of.

The shafts at Gedling, situated three miles north-east of Nottingham, commenced in the Trias, to which formation the first 461 feet may be attributed; this was underlain by 47 feet of light grey Permian marls, with a breccia 8 ins. thick forming the base. The Coal Measures were then entered, of which the first 20 feet are described as "red rock," but of which specimens were, unfortunately, not seen. About 7 feet of mingled ground

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Mr. Gibson. was then passed through, beneath which the shafts penetrated 100 feet of red and mottled marls to a depth, from the surface, of 637 feet, below which they were continued in ordinary grey and black Coal Measures containing seams of coal, and finally were considered to reach the Top Hard at a depth of 1,368 feet.

From the Top Hard up to a depth from the surface of about 850 feet, the rocks were mainly grey in colour, the bulk of the material being blue or grey shales, with an occasional bed of black shale associated with seams of coal, and containing numerous specimens of *Carbonicola*, together with plant and fish remains, the specific characters of which have been kindly determined by Dr. Wheelton Hind. At a depth of 1,110 feet or 258 feet above the Top Hard, a blue shale, with *Lingula* mingled with fragmentary plant remains, was met with, so that this stratum is evidently of marine origin. A similar bed (blue clunch of the sinker's record) at a depth of 844 feet, yielded large forms of *Lingula* and *Discina* in association with fish remains, consisting of scales of *Coelacanthus*, and, excepting the head portion, a nearly complete specimen of *Acanthodes Wardi*. This marine band overlies a thin coal, and to whatever origin—whether formed of drifted material or of vegetable matter grown *in situ*—the seam of coal be attributed, it was evidently quickly buried under marine sediments. Thus two marine horizons have been detected among the rocks overlying the Top Hard Coal, and, considering the difficulties attending the examination, where time did not permit a daily visit, it may well be asked if a larger portion of the Coal Measures were not deposited under marine conditions than has hitherto been suspected.

The strata, overlying the marine shale at 844 feet, consisted of grey and black shales containing a band of dark brown laminated ironstone, with many fragmentary specimens of *Anthracomya Phillipsi*. A reference to previous reports will show that exactly the same type of strata, with the same fossil, succeeds the chief coal-bearing strata of North Staffordshire on the western side of the Pennine axis. The identity in character of the Coal-measure sequence on either side of the Pennine Chain is further confirmed by the red and mottled marls which immediately succeed the shales with *Anthracomya Phillipsi*. These red beds, about 100 feet thick, so closely resemble, in all all respects, the Etruria Marls of North Staffordshire, the Brick clays of the South Staffordshire, the Ruabon terra-cotta marls of the Denbighshire, and the red marls of the Warwickshire coalfields, as well as the red marls of the Thurgarton * boring. which, in all cases, overlie the top beds of the Productive Coal Measures, that there seems no escape from regarding the Coal Measures of the Midlands as having been deposited over one continuous basin, and that the Pennine elevation, with the consequent breaking up of the syncline, was long subsequent to their deposition.

* W. Gibson. *Quart. Journ. Geol. Soc.* Vol. lvii. 1901.

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Mr. Gibson.

The fact that at Gedling the Permian breccia immediately overlies the red Etruria Marls, whereas at Thurgarton the red marls are overlain by grey and red sandstones comparable to those above the red marls of North and South Staffordshire and Denbighshire, indicates that the Thurgarton boring was put down on the easterly dip and probably towards the centre of a concealed Coal-measure basin; for south of Gedling, at the Clifton Colliery, these higher measures are absent; while the Coal Measures, instead of being inclined eastward, dip northward, thus supporting the original idea held by Sir Andrew Ramsay that a syncline of Coal Measures underlies the Trent north-east of Nottingham.

The shafts of the Sherwood Colliery, near Mansfield, commence on the fringe of the Trias. Beneath this, which is not more than 30 feet thick, they penetrated the Magnesian Limestone series, also with a strong breccia at the base, and entered the Coal Measures at a depth of 251 feet, of which the first few feet consisted of brown shales with numerous plant-remains, resting on a strong reddish sandstone in which plants were also abundant. Below this the strata consisted of grey and black shales with thin bands of grey sandstone and seams of coal, the general type resembling the Gedling sequence above the Top Hard, so far as the deeper shaft had been carried (192 yards) at the time of our last visit. At 560 feet a dark blue shale (black bind), 4 feet thick, contained numerous large specimens of *Lingula*, not occurring in a single stratum but lying throughout the whole band. No trace of the red marls or underlying black and grey shales with *Anthracomya Phillipsi* were found; and there seems little doubt that the Permian of the Sherwood Colliery rests on a higher horizon than at Gedling, but definite conclusions must necessarily be left till the shafts have been continued down to the Top Hard, and more of the coalfield has been examined.

The examination of the Sherwood and Gedling sinkings shows that, whenever an opportunity occurs of searching over a large quantity of material of the Coal Measures, marine organisms are not infrequent. The same result has been obtained from the long section opened to inspection by the recent widening of the Midland Railway between Doe Hill and Clay Cross. Here, at a spot 300 yards north-west of Padleywood Farm, some grey shales containing large specimens of *Avicalopecten* (*Pterinopecten*), *Lingula*, and *Gonatites* in great abundance occur on an horizon as yet undetermined, since the surrounding area has not been examined, but situated somewhere below the Top Hard and Deep Soft, and therefore on quite a distinct horizon from those at Gedling and Sherwood.

Since this section is rapidly being obliterated the following details, giving the approximate thicknesses, are given:—

[Section Showing Position of the Marine Bands.]

(Midland Railway between Pilsley Junction and Clay Cross.)

| | Ft. | In. |
|---|---|---|
| Pale grey shales and ironstone bands - - - | 20 | 0 |
| Black shales with *Carbonicola* - - - - - | 6 | 0 |
| COAL - - - - - - - - - - | 3 | 10 |

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Mr. Gibson.

Section Showing Position of the Marine Bands—contd.

| | Ft. | In. |
|---|---|---|
| Grey sandy shales | 8 | 0 |
| Grey sandstone | 3 | 0 |
| Grey sandy shales | 10 | 0 |
| Grey sandstone | 6 | 0 |
| Blue sandy shales with ironstone bands | 15 | 0 |
| Black shales with *Carbonicola* | 5 | 0 |
| Light Grey sandy shales with ironstone | 8 | 0 |
| Black shales with *Carbonicola* and Ironstone courses | 25 | 0 |
| Dark shales with *Lingula*, *Aviculopecten*, *Goniatites* | 4 | 0 |
| Grey sandstone | 8 | 0 |

The cutting is continued through several yards of strata above and below this portion of the section, but further measurements were not possible.

The chief point of interest obtained during the year in the examination of the Coal Measures, is undoubtedly the discovery of the marine character of portions of these beds, both high up and low down in the sequence. Judging from the recent work of Mr. J. T. Stobbs in North Staffordshire, and considering the very limited area so far examined in Derbyshire, other horizons no doubt await investigation; and it is hoped that they will be equally serviceable in correctly determining the position of some of the seams of coal as they have proved to be in North Staffordshire. In connection with this the occurrence of a marine bed below the Ackworth or Brierley rock in the Yorkshire coalfield* and of a simliar band below the red rock of the Sherwood sinking may be mentioned.

## PERMIAN.

Considering that the area surveyed during the year contains only a very small portion of this formation, and this where it is on the point of dying out, little more can be done than to indicate the direction in which the inquiry seems to be trending. The field evidence shows most conclusively that, while the break between the Magnesian Limestone series and the Coal Measures is everywhere great, it is impossible to demonstrate any such discordance with the Trias; in fact, the evidence of the marl-pits at Cinderhill reveals the closest connection. The unconformity with the Coal Measures can be detected at the Great Northern Station at Kimberley, where the basal breccia reposes at a very gentle angle on the slightly more inclined and truncated strata of the Coal-measures. This relationship was once still more evident in the cutting at the Midland Station as described by Mr. E. Wilson. Traced southward from Kimberley, the Magnesian Limestone passes from higher to slightly lower beds; while eastwards it rests on higher horizons, until at Gedling, as we have previously (p. 13) seen, the basal breccia lies on the red Coal-measure marls occurring 286 yards above the Top Hard Coal.

The basal breccia is worthy of close attention. At the outcrop at Kimberley it is 2 feet 10 inches thick; at Gedling, which is

* Geology of the Yorkshire Coalfield, *Mem. Geol. Survey*, p. 471.

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situated seven miles to the east of the outcrop, it is only 8 inches thick; while at Sherwood, near the outcrop, the thickness is 8 feet. This indicates a marginal deposit, which receives further confirmation from the coarse angular nature of the rock at Kimberley and Sherwood, where it consists of angular fragments of quartzite and large rounded and sub-angular blocks of limestone and other Carboniferous rocks: its resemblance to the dolomitic conglomerate of the Trias becoming in this case very striking. The numerous blocks of Carboniferous limestone in the breccia at Sherwood indicate that the Pennine Hills existed as a belt of high ground at the commencement of the Permian period; and that here, as in other areas, the period of greatest movement preceded the deposition of the Magnesian Limestone Series. Mr. Gibson.

Reference may be made to the small patches of Permian represented on the old edition of the Survey Map at Morley and Dale Mill. The field evidence entirely confirms the statement of Mr. E. Wilson,* that "the Permian of Morley consists of brecciated Lower Bunter and purple Lower Coal Measures, and that at Dale Mill of massively bedded Coal-measure sandstone." The latter is in fact the rock associated with the measures above the Kilburn Coal.

## TRIAS.

Considerable difficulty has been experienced in mapping the sub-divisions of the Trias, both from the great unconformity which exists, and also from the very attenuated character of the beds themselves. When it is realized what a difference of altitude there must be between the crests of the Millstone Grit and other rock-features, and the troughs of the shale valleys on the pre-Triassic land-surface; and also that the total thickness of the Bunter here is sometimes not more than 20-feet, while the Keuper Sandstone is also thin, and that consequently there is frequent overlapping of the lower sub-divisions of the Trias by the higher, as well as great and rapid variations of thickness in the Bunter, it will be seen that the surface distribution of the Triassic sub-divisions must be complex. On the western side of the area the difficulty is increased by the amount of Drift which obscures the ground, and by the paucity of exposures. Mr. Wedd.

### BUNTER.

In the western part of the district the Bunter, where thickest, is a coarse yellow pebbly sandstone, often with strong shingle beds; but it often deteriorates into merely a few feet of gravelly sand. About Cumberhill, Quarndon, and Allestree the thicker parts are denuded into the characteristic nabs and combes. To the east of the Derwent in Croft Wood near Breadsall Station some very interesting sections of the basement beds are seen. A few feet of hard and compact fine-grained yellow strongly-calcareous sandstone, very similar to the sandy "Magnesian Lime-

* *Midland Naturalist*, vol. iv., 1881, p. 100.



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Mr. Wedd. stone," mapped as Permian, a few miles farther east, underlies and apparently passes up into normal yellow soft pebbly Bunter. This hard calcareous sandstone has here at its base a thin breccia with angular fragments and hollow calcareous nodules lined with calc-spar. In one weathered section a coarse grit, full of small angular and rounded fragments of Millstone Grit and of red and green sandstone and marl, is seen, with pebbly Bunter a few feet above. The breccia doubtless represents the "Permian Breccia" farther east. It is underlain in this section by 1 foot 6 inches of white and bright red plastic marl, but whether this latter should be assigned to the Bunter or to the Pendleside shales is uncertain.

Mr. Gibson. The marginal character, perplexing variation, and great unconformity of the Trias to the Carboniferous rocks on the southern margin of the Derbyshire Coalfield, which here constitutes the chief feature of the formation, cannot be more suitably demonstrated than by giving, in brief, the relationship and sequence met with in the numerous sections between Morley and Stanton. In the cutting of the Great Northern Railway at Morley* the Triassic rocks dip westward at fifteen degrees, whereas the Coal Measures on which they rest with a natural junction are inclined to the north-east. The formation here consists of a lower portion of soft red non-pebbly mottled sandstone and bands of breccia of a united thickness of about 70 feet, overlain by about 25 feet of pebbly sandstone, succeeded by flags and marls which evidently belong to the Waterstone sub-division, since Keuper marls come in a short distance to the north. Retaining the sub-divisions of Professor Hull we have here representatives of the Lower Mottled Sandstone, Pebble Beds, and Waterstones. About two miles to the south-east in a quarry at the Hagg, a slightly brecciated and pebbly sandstone rests directly on the Coal Measures, which are to be seen in the floor of the quarry. The Pebble Beds therefore here rest directly on the Carboniferous. In the next quarry 150 yards to the south-east, we find a non-pebbly sandstone, about 50 feet thick, overlaying the Coal Measures, and succeeded by a pebbly, slightly brecciated sandstone 15 to 20 feet thick, which is overlain by thin flags and shales with a thin bed of conglomerate at the base. The same sequence is repeated in the quarries to the south, and leaves no doubt that we are here dealing with the Lower Mottled Sandstone (non-brecciated), the Pebble Beds (slightly brecciated), and the Waterstones—always supposing that the lithological characters which have been deemed sufficient to establish these sub-divisions in adjacent and other Triassic regions are here adhered to. It is noticeable that the Bunter Sandstone in the quarry is impregnated with barium sulphate, while the Keuper is not; for farther east, in the Bramcote area, this mineral has been supposed to indicate the Keuper age of the sandstones. The same sequence appears to hold good for a mile to the east of the Hagg; then, after passing a narrow break in the ground, a

* See E. Wilson, *Geol. Mag.* for 1880, p. 308.

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quarry has been opened out showing red and mottled non-pebbly sandstone, 40 to 50 feet thick, succeeded conformably by about 10 feet of flags and marls with a thin bed of conglomerate at the base, and passing up into red marls which continue to crop out to the south up to the alluvium of the Trent. The middle sub-division of the Bunter thus suddenly vanishes, but makes its appearance again at Stanton by Dale half a mile to the east. Mr. Gibson.

At Sandiacre and Stapleford it forms some conspicuous crags, and appears to somewhat increase in thickness between here and Nottingham. Its junction with the Keuper to the south is very abrupt, but whether this is due to faulting or unconformity is not very clear.

To the north of the main outcrop of Trias, between Bramcote and Wollaton, detached patches of Bunter have been met with in Broomhill Wood, north of Wollaton, Balloon Wood, north of Bramcote Moor, and in the Catstone Hills, where an unusually hard conglomerate forms the capping of the hills. Between Strelley and Strelley Windmill, a belt of relatively high ground is capped with sand and gravel, but whether these result from the weathering of Triassic rocks, or belong to the Drift, the evidence is not sufficient to decide.

The capriciousness of the sub-divisions, if they can be so called, of the Bunter between Morley and Stanton is thus very evident. Their unconformity with the Carboniferous strongly reveals itself along this line, not only by the Trias resting on very different horizons, but also by the two systems being inclined in opposite directions. The idea of the Trias being here a marginal deposit at once enforces itself, just as the examination of the Magnesian Limestone series on the eastern side of the coalfield conveys the same impression, and plainly shows the gradual depression of the ancient hilly region of Derbyshire, first beneath the waters of the Magnesian Limestone period, followed by its gradual burying up by the Trias.

### KEUPER SANDSTONE.

In the old quarry west of Allestree Farm, typical Keuper Waterstones are seen passing up into normal Keuper marl, but in the intermediate ground between here and Morley no sections are exposed. In the railway cutting at the latter place, thin flags of typical Keuper sandstone appearance are seen overlying Bunter. Mr. Wedd.

At Stapleford the Lower Keuper Sandstone forms a broader outcrop, the greater part of the west side of the village being built on this formation. At the east end of the village it is thrown up by an east and west fault, and caps the hill at Bramcote and at Beeston Fields. Mr. Fox-Strangways.

Between Bramcote and Lenton Park on the edge of the map the Trias is evidently crossed by an east and west fault, running along the valley separating Bramcote village from the hills to the north; while at Lenton the ground is further complicated Mr. Gibson.



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Mr. Gibson. by a system of faulting that has not yet been worked out. In the Bramcote and Stapleford Hills we find little evidence in support of the Keuper age of the rock capping the Himlack Stone, Bramcote and Stapleford Hills; but we hesitate to express any opinion on this point till the ground around Nottingham and to the north has been examined.

### KEUPER MARL.

Mr. Fox-Strangways This formation covers the whole of the range of hills along the southern edge of the map between Derby and Beeston. It consists of the usual red marls with many thin beds of grey skerry sandstone; which are, in most cases, too thin to trace across the country. A band near the base of the formation is rather more persistent than the others, and forms a feature that may be followed more or less easily from Derby to the Erewash Valley. In Chilwell brickyard a thick mass of this sandstone is brought up on the south side of a fault. This bed has a thickness of from 20 to 30 feet or more, and is of greater importance than the Upper Keuper Sandstones have been found to be anywhere in this district. Although it represents these in lithological character, its great thickness almost suggests that it might possibly be the upper part of the Lower Keuper Sandstone. Throughout a part of its course, the Keuper marl comes on regularly above the Lower Keuper Sandstone; but in many cases its northern boundary is very abrupt, and it is either faulted or banked against the lower formations. It dips regularly to the south; but whether the beds are broken by faults, as shown on the old map (71° S.W.) there is not sufficient evidence to prove. These faults were probably put in from apparent breaks in the features formed by the thin skerry sandstones, but these beds are far too impersistent to be a reliable guide in the matter.

The higher part of the ground formed by the Keuper marl is, in many cases, covered by Boulder-clay, and that bordering the Trent valley by large deposits of gravel, which also help to obscure the general structure of the country.

### PLEISTOCENE.

#### *Glacial.*

Mr. Gibson. Considerable interest is attached to the glacial deposits of this district, from the fact that we here appear to have reached the limit in a N.W. direction of the Chalky Boulder-clay or Eastern Drift. The fieldwork has not as yet been carried sufficiently far to be sure on the point, or to be able to say what was the nature of the glacial action beyond this district along the foot of the Pennine range. Consequently, we cannot at present offer any suggestion as to the course of events that took place in this area, which appears to have been the spot where the great glacial system of eastern England impinged on the local Pennine glacier that separated it from the general western glaciation.

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The eastern ice, in its advance westwards up the Trent valley, does not appear to have possessed more force than was sufficient to push its *debris* much higher than the 400 feet contour, for chalk flints are not found much above this elevation. Mr. Gibson.

That the Pennine glacier impinged on the eastern ice is clear from the fact that numerous scratched blocks of Carboniferous Limestone and Millstone Grit are found on the high ground to the south of Morley; but the absence of any relics of the glacial age within the broad basin of the Erewash Valley, though present on the surrounding high ground, is very striking, and suggests that the valley must have been held by clean ice during the deposition of the surrounding Boulder-clay.

The principal deposit of Eastern Drift, that is, clay with Chalk flints, occurs on the high ground at Risley Park at an elevation of about 430 feet. A few flints are seen in the clay about Spondon, but the great mass of this clay contains principally pebbles, and consequently is derived from the west. It is, however, of considerable thickness, a well at the village going through as much as 90 feet of Boulder-clay. This Boulder-clay extends to the north, and is found on the other side of the brook as far as Chaddesden Common and beyond.

In the western part of the area the Drift, for the most part, occupies ground of an altitude intermediate between the highest hills and the valleys, being found in consequence chiefly in the north of this district. It does, however, also occur on some of the higher ground and runs down, or has slipped down, into the valleys. It occupies most of the undulating tract of Keuper Marl south-east of Breadsall, but south of that village there is a considerable area of Marl quite driftless. It also partly covers the flat plain north-west of Morley and the Carboniferous shales north of Breadsall; where red Boulder-clay, sometimes overlying yellow loamy Marl, is banked against and creeps over the escarpment of the grit (*d*). Between Little Eaton and Milford a flat spread of red and brown Boulder-clay with cherts and limestones seems to cap all the high ground of Duffield Bank, entirely smothering the grit (*c*), the dip slope of (*d*) and the escarpment of (*c*) (*p.* 11). A patch of red stony Boulder-clay caps the Coal Measures between Horsley, Horsley Woodhouse, and Kilbourne. West of the Derwent some of the high ground north of Hazlewood is drift-covered. The Boulder-clay consists of red and yellow or light-grey clay, both often sandy, and presumably made of local material; the former largely made up of Triassic detritus occurs to the south-east of Breadsall, while the latter which consists chiefly of Coal-measure shales is found east of Breadsall and north-west of Morley. Mr. Wedd.

The Drift over all this area is entirely local, the boulders always belonging to rocks of the neighbourhood, chiefly Carboniferous grits and sandstones, Mountain Limestone and

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Mr. Wedd. Cherts, with now and then a basic igneous rock, presumably Toadstone, and Bunter pebbles. The only place where a single north-country boulder has been found is north of Hazlewood, where a striated dark green andesite with garnets, like the basic andesites of the Lake Country, so abundant in the Western Drift, was found in some thin Boulder-clay. No trace of Eastern Drift has been found in this part of the district. There are no Chalk fragments in the Boulder-clay, but plenty of grey and black cherts occur, which might equally well be chalk flints as far as their lithological appearance goes, but the fossils found in them are invariably Carboniferous. The only indication of Glacial transport on the high driftless tracts of Carboniferous rocks is that here and there a few limestone and chert boulders may be seen. In several places high up on the flanks and edges of the Derwent and tributary valleys, there are coarse gravels with water-worn pebbles, occasionally passing under Boulder-clay. The position of these suggests their formation as torrential deposits, formed by water percolating between the edges of local glaciers and the solid flanks of the valleys. They also sometimes form esker-like ridges parallel to the valleys. At the Derby Corporation Waterworks at Little Eaton, this gravel has been found to be continuous down the slope of the hill with the recent river gravel under the alluvium. A detailed examination of samples, kindly furnished by Mr. Freeman, showed that though the pebbles of both were similar, the percentages were widely different, and the composition of the Derwent valley gravel was strictly such as might be expected considering the drainage area; while that of the Glacial gravel above the valley contained, besides other points of difference, a much larger percentage of Coal-measure pebbles. The present continuity of the two gravels is no doubt due to slipping of the glacial deposit down the slope. Except the gravel ridges, themselves sometimes obscured by Boulder-clay, the lie of the Drift is flat and featureless, with a general absence of mounds.

### RECENT.

Mr. Fox-Strangways. The post-glacial gravels and other beds of the Trent valley were noticed in the last summary for 1901, and we have little to add to that description. The 'high-level valley gravels' just come into this map to the south of Spondon, and probably occur at Beeston, but they are so intimately associated with the gravel terraces of the Trent, that no satisfactory division can be made between them. Well-formed river terraces occur west of Chilwell and at Beeston at about the 100 feet contour. These gravels are composed principally of quartzite pebbles and flints; the upper part is sometimes more clayey, and the pebbles and other fragments are often vertical, showing signs of disturbance, which has been attributed by Mr. Deeley to glacial agency.*

* *Quart. Journ. Geol. Soc.*, vol. xlii., 1886, p. 466.

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The alluvium of the Derwent valley consists for the most part of silt overlying coarse gravel. Near Little Eaton and Breadsall as found at the Derby waterworks, the silt is always about 4 feet thick, the gravel below varying from 6 to 14 feet, resting on a generally level floor of shale, with a few beds of thin grit. Near Holme Nook, south-west of Breadsall, a vegetable deposit with nuts and other plants, was found below the gravel at 10 feet from the surface. This appears to be a similar deposit to that in the Erewash Valley at Sandiacre mentioned in the Summary for 1901 (page 10) as containing recent shells. The alluvium of the Trent at Beeston is mostly gravel and varies in thickness from 13 to 21 feet. Mr. Wedd.

## ECONOMIC GEOLOGY.

In the western part of the district the grits and sandstones are used for building, paving, roadmaking, and the manufacture of scythestones and grindstones; the Millstone Grit being noted for the excellence of the latter, and for building-stone where great strength and durability are required. These beds do not, however, form a lasting roadstone; the main roads of the district are generally made with the igneous rocks derived from the older formations further south. Mr. Fox-Strangways.

The principal brickclay of the country is the Keuper Marl, which is extensively worked at Derby and at Chilwell, but does not at present appear to be utilized between these points, probably from the fact of the easy railway communication which has stifled out the smaller works. The Coal-measure clays are also used for brickmaking at many places; and pottery is made from them at Derby. The Boulder-clay was formerly used for brickmaking at Spondon, but these yards are now closed.

The sands in the lower part of the Trias are used for building purposes, and a valuable moulding sand has until recently been obtained from these Measures near Stanton.

The best agricultural land is over the Keuper Marl to the south; and the largest area of arable land is consequently found on that formation. A great part of the country is, however, devoted to pasture; but, in a district like this, where the mineral wealth is so considerable, agriculture is of secondary importance.

The main water supply of the country is undoubtedly to be obtained from the Millstone Grit rocks, but a sufficient area of these beds has not yet been surveyed to show their capabilities. These rocks are tapped beneath the Trent valley in the district to the south for the supply of a large number of towns and villages between Long Eaton and Swadlincote, which is a proof that the water obtained from them is both good and abundant. The Bunter would also afford a pure water; but the beds are far too thin, and the outcrop too limited, to furnish anything more than a local supply.

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## 2. London District.

Mr. H. B. Woodward, F.R.S., District Geologist (Acting).
Mr. T. I. Pocock, M.A.
Mr. J. Allen Howe, B.Sc.

### EOCENE, PLEISTOCENE AND RECENT.

Mr. Pocock and Mr. Howe.

The mapping of the gravels and brickearths of the Thames Valley, not previously surveyed on the six-inch scale, was carried out over a large tract west of London as far as Uxbridge, West Drayton, Colnbrook and Staines, and east of London along the Lea valley to Enfield, and in the main valley to Romford, Upminster, and Grays.

A much larger area of brickearth as at Harmondsworth and Harlington has been mapped, although over considerable tracts the artificial removal of the earth for brickmaking has exposed the underlying gravel. Again in the fruit and market garden district of Heston, Feltham and Laleham much more brickearth will be shown on the new map than was represented on the old.

The attention of Mr. Newton was called to some mammalian remains from the alluvium of Staines Moor, and he has identified them as belonging to the true elk, *Alces machlis*.

Larger tracts of brickearth than had been previously recognised, have also been mapped in the Lea valley, around Ilford and South Ockendon in Essex. A new tract of chalky Boulder clay underlying the brickearth has been observed by Mr Pocock to the north of Upminster, and not far from the mass of Boulder clay beneath the gravel at Hornchurch, to which attention was first directed by Mr. T. V. Holmes.

Mr. Howe.

The *Great Western Railway* to High Wycombe and the extensions of the *Great Central* and *Metropolitan Railways* in the same district have been examined by Mr. Howe during the summer, but it is not considered advisable to publish any account of the geology until the works are more nearly completed. Most of the ground opened up is wholly occupied by London Clay, but the section of the line between the Colne Valley and the Misbourne has good exposures of Drift, London Clay (?) and Reading Beds. About Gerrard's Cross nearly 20 feet of the Drift is cut through.

Information obtained from the railway works has necessitated some minor changes in the mapping near Ickenham and Ruislip, by the introduction of a couple of patches of Reading Beds at the latter, and an increase in the existing area at the former place. Indeed, in the neighbourhood of these villages the Reading Beds appear to come very near to the surface, and probably occupy more area than can be shown by definite boundary lines.

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## 3. Southern District—Devon and Cornwall.

Mr. Clement Reid, F.R.S., District Geologist.
Mr. W. A. E. Ussher.
Mr. J. B. Hill.
Mr. D. A. MacAlister.
Mr. J. B. Scrivenor, M.A.
} Geologists.

### PALÆOZOIC.

Though the year 1903 will probably see the linking together of the eastern and western areas in Cornwall, yet there is still so much uncertainty as to the age of the slates in the western area that it will be convenient to deal with the sedimentary rocks of the two areas separately.

In the western area the mapping has been carried on by Mr. Hill from Falmouth and Truro, and has entailed the further examination of the Mylor, Falmouth, and Portscatho divisions, the lithological characters of which have been described in former reports. Mr. J. B. Hill.

To the west of Truro the strike of the beds bends round to the westward, as a result of which the Mylor Series is partially encircled by the Falmouth and Portscatho Series, which swing round them; this westward sweep bringing the two latter divisions within the mineral districts of Chacewater and St. Day has involved them in the mineralisation which has affected that area. The mineralisation has produced a marked change in their normal appearance in the field. For a depth of many feet from the surface, the slates are deeply tinted with varying hues of red, yellow, and pale gray, resulting from the oxidation of the iron ores with which they have been charged. As a consequence, the leading characteristics of the divisions have been masked, and their identity has to be determined from deep sections below the limits of surface decomposition.

The rather fine-grained conglomerate which occurs in the neighbourhood of Grampound and Probus has not been observed in this district west of the Tresilian River, so that its precise relations with the Portscatho Series, amongst which it occurs, has not been established. It forms a strong band however, differing in character from the small sandy intercalations so common a feature in the Portscatho Series; and it may possibly represent an unconformity.

For part of the year Mr. Dixon worked also in the same Map (352), continuing to trace the outcrops in a north-easterly direction, and helping to connect the Land's End area with that near St. Agnes. In the south-western part of this area the strike remains north-easterly, as it is around Hayle; but towards the northern edge of the Map it curves more to the east, in agreement with the adjoining district around Truro. Mr. E. Dixon.

Some purple and green silty strata which Mr. Dixon has been able to map as a definite belt between the Mylor shales and the sandy Portscatho (= Hayle) Series, seem to be equivalent, in part at least, to the Falmouth beds mapped by Mr. Hill. They Mr. C. Reid.

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Mr. Reid. are well developed near Porthtowan and certainly extend westward to Godrevy; beyond that point it has not been found possible to map them as a separate division, partly owing to the obscurity of the ground, partly because they appear to have so thinned out as to be scarcely recognisable. Perhaps a trace of these rocks is seen in the banded silty beds in the cliff immediately west of Lelant Towans (Map 358), though within the aureole of metamorphism lithological characters become greatly altered.

Mr. J. B. Scrivenor. This work was continued northward during the latter half of the year by Mr. Scrivenor, who examined the area lying between St. Agnes, St. Allen, and Newlyn East. In the course of the survey it was found that the strike of the Hayle Sandstone curves round, to join up with rocks mapped by Mr. Hill as the Portscatho Series, and there seems little doubt that the two sandy divisions are one and the same—we can therefore get rid of the term Hayle Sandstone. As to the Falmouth Series, in this area there is great difficulty in separating it from the Portscatho Series below and from the Mylor Series above; but it it seems to be represented by the silty and often purple and green deposits mapped during 1901–2 by Mr. Dixon. The suggestion of an inverted sequence, made in last year's Summary by Mr. Reid, is not borne out, it now seeming clear that the Mylor Shales are the highest division in this area. The dip, therefore, is on the whole normal, though the strata are often folded and contorted on a small scale. Another argillaceous division makes its appearance in the area north of Perranzabuloe and Zelah, rising from beneath the Portscatho sandy beds. These "Perran Shales" are distinctly separated from the Portscatho series, as can be seen on the north beach at Perranporth; moreover, there is no difficulty in following the boundary inland, when once the peculiar weathering of these shales has been recognised. Except for a band of shales with coarse felspathic mudstones, approximately 150 feet thick, the group consists entirely of deep black and grey non-calcareous shales. The shales are best seen in the bay next but one north of Cotty's Point. The black shales appear dull and silty in section, but when a cleavage face is exposed they are seen to be lustrous; the grey shales do not show this. The banding is not always apparent, but a careful examination enables one to recognise it; and in the little bay mentioned above it is beautifully shown. A peculiarity of the Perran Shales is that the amount of quartz-veining is on the whole much less than in other divisions of the killas.

The weathering of the Perran Shales can be studied along the coast north of Cotty's Point. There is one spot, between the adit of Wheal Vlow and the Wheal Bryan Lode, where all its gradations appear in a small mass of rock. First, the dead black of the shales begins to disappear, a dull green colour gradually taking its place. This green becomes more and more pronounced as the black fades, and then in its turn fades away also, leaving almost pure white shales, a remarkable instance of bleaching.

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## OLD RED AND DEVONIAN.

Mr. Reid. As already remarked, great difficulty has been met with in previous years in making out the succession of the rocks in West Cornwall, where they are greatly disturbed and unfossiliferous. An attempt was therefore made in 1902 to unravel the sequence in Sheet 346, especially near Newquay. Here the rocks, though greatly disturbed, are fossiliferous, and it was hoped that a careful study of the cliffs might show the true structure and succession, and help in the determination of the age of the strata further west. A succession has now been made out, some approximate measurements have been obtained, and a beginning has been made towards the division of these rocks into palæontological zones. Much remains to be done, and the linking up with the western area is still incomplete.

The results thus far obtained are as follows:—An anticlinal arch in Watergate Bay brings up something like 1,000 feet of alternating purple and green strata, which contain *Pteraspis* and other fish-remains from top to bottom, as already recorded by Mr. Howard Fox*. This slightly calcareous mass of silt and shale is obviously of Lower Old Red Sandstone age, and is apparently also the equivalent of the purple slates of Dartmouth, as was long ago suggested by De la Beche. No base has been reached in Watergate Bay, the centre of the arch only exhibiting purple and green silts with *Pteraspis*, exactly like the strata which overlie them. Towards the upper part there is some trace of a lithological passage into the marine Lower Devonian strata; but the fossils of the two deposits are entirely distinct, and no alternation has yet been discovered. The Lower Devonian seems to rest quite conformably on the Lower Old Red. The Lower Old Red near Newquay has thus far yielded nothing but fish-remains; it contains no mollusca, no definitely marine organism, and no other fossils, unless among the obscure, badly mineralised plates may be eurypterid remains as well as fragments of *Pteraspis*. The fishes collected in the course of the Survey and determined by Mr. E. T. Newton are *Gyracanthus*? *Pteraspis cornubica*, *Parexus recurvus*? Coccostean plates, and plates belonging to an undetermined genus of ganoids. *Cephalaspis? Carteri* probably belongs to these beds, for the specimen in our Museum, labelled 'St. Columb Porth,' is in a matrix like that of the Old Red, and the parish of St. Columb extends into Watergate Bay. Smaller fragments perhaps belonging to the same form were collected in 1902 in the *Pteraspis*-beds.

Ignoring for the present a few feet of doubtful strata, which may represent passage or transition beds, though they have yielded no fossils, we next come to a great thickness of grey calcareous shales, which extend from Watergate Bay, past Newquay, at least as far as the Penhale Sands. Making every allowance for the repetition of the same bed through overthrusting, there would seem to be at least 1,000 feet of these

* *Trans. Roy. Geol. Soc., Cornwall*, vol. xii., p. 342, and *Geol. Mag.* for 1900, p. 145.

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Mr. Reid.

strata. A series of marked beds may reappear several times, but gradually as we travel southward each successive horizon or zone sinks beneath the sea-level and is replaced by rocks having a slightly different lithological character and containing quite different fossils; the lithological change, however, is very slight and gradual.

The principal cause of the great difficulty that has been felt in making out the succession near Newquay, lies in the occurrence in great numbers of overthrust faults, all hading in the same direction, and, on the south side of the anticlinal axis, all dipping at an angle only varying slightly from that of the bedding planes in the rocks which they traverse. The southward dip varies from 30°, north of Porth, to 90° or even 95° (a slight overturn) near Ligger. If this were a true dip the thickness of the strata would be enormous; but the effect of the overthrusting seems to be almost to cancel the dip, the net result being equivalent to a flattened arch, with the strata in the southern limb dipping southward at an angle of not more than 4° or 5°. On this part of the coast there is little contortion and the cleavage being parallel to the overthrusts, nearly corresponds to the bedding as shown by the fossils.

On the north side of the arch, the strata are more confused; but the overthrusting evidently tends to cut out beds instead of duplicating them. It is interesting to notice that here the cleavage, parallel to the overthrust planes (which are inclined usually at about 45°), cuts across the bedding as shown by the fossils. Though at first sight the strata seem more easy to understand in the northern limb of the fold, yet it has been found extremely difficult to obtain a succession there—we can allow for repetition of beds; but it is very difficult to make allowances for strata entirely cut out. This northern limb of the anticline has only yet been imperfectly studied; but the beds will be noted in the description of the cliff-section as far as the succession has been made out.

Without going into much detail we will now describe the cliffs near Newquay; or rather, as this part of the coast is greatly indented and broken, we will describe shortly a generalised section at right angles to the strike, and only in a general way corresponding to the cliffs.

The crest of the anticline will be found in Watergate Bay, between Horse Rock and Creepinghole Point. The strata consist of alternating beds of purple and pale-green colour. They are fairly fine-grained, seldom deserving the name of sandstone; and sometimes the purple bands are so smooth and fissile as to merit the name of slates. These strata cannot be less than 600 feet; but they are so uniform that it is impossible to say what is the exact effect of some of the faults. Close search shows that badly preserved remains of *Pteraspis* occur throughout, the lowest yet seen being about 100 feet up in the series, close to the centre of the anticline.

On each side of the anticlinal axis these purple and green strata are followed by similar deposits containing occasional bands of

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black shale full of *Pteraspis*. Gradually the purple beds dis- Mr. Reid.
appear, and are replaced by pale-green strata with rare *Pteraspis*. These pass up into alternating films of black and green shale, much silicified, and ending with a thin sandstone seen in the cliff north of Fern Cavern, and again met with on the other side of the anticline in Stem Cove. Whether these uppermost beds should be classed with the strata above or below is still somewhat doubtful; they seem to form a transition, but have not yet yielded fossils. The thin sandstone has been taken as the provisional boundary.

Next follow 50 feet of dark-grey more or less silicified slates, in which some indeterminable brachiopods occur, as well as traces of crinoids. These Lower Devonian rocks appear to be entirely of marine origin. The succeeding strata are dark grey or rarely brownish calcareous shales, with thin seams of much sheared limestone, and pale-green marly streaks, perhaps representing volcanic ash. These rocks contain numerous badly-preserved fossils, the best of which are inclosed in black nodules, proved by Dr. W. Pollard to contain a considerable percentage of phosphate. The fossils are always marine, consisting principally of crinoids, compound and simple turbinate corals, and *Bellerophon*. An abundant, but much compressed, organism, with bilateral symmetry and median septum, suggests *Calceola*, though certainly not the Middle Devonian form. This part of the series is so much repeated by overthrust faults that it is impossible yet to give any measurements. All that can be said is that the apparent dip of about 40° near Newquay is nearly neutralised by constant overthrusts from the south. Though the same bed may reappear several times, it gradually gives place to newer strata, with different fossil contents and slightly different lithological characters. The strata found at Newquay and Porth seem to reappear with similar characters and fossils on the north side of the axis in Beacon Cove.

Near the south end of Fistral Bay another set of beds is entered. These consist of harder shales, slightly calcareous, and dark grey. In them occurs 10 feet or so of highly fossiliferous, much-sheared shales and thin limestone. This bed is full of a fan-shaped or spheroidal tubular coral, not seen in other sections; it yields also obscure crinoids, brachiopods, and simple turbinate corals. The common fossil suggests *Alveolites*, or perhaps a Monticuliporoid, though it is too badly preserved for microscopic examination.

Very hard grey shale, alternating with thin grits, form Pentire Point East. These, perhaps, form the beginning of a new series, characterised by greater abundance of the pale-green calcareous seams which may represent ash-beds. The sandy beds have as yet yielded only two fossils, both of which seem to be badly-preserved lamellibranchs, one of them perhaps a *Cardiola*, different from anything in the rocks nearer Newquay. As these rocks are followed southward they dip at a higher angle and become more shattered. In them at Kelsey Head occur two thin greenstone sills (or perhaps one sill repeated by overthrust-

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Mr. Reid. ing. This sill is traceable along the strike for two miles inland. Mr. W. D. Barnes, who helped in the examination of this part of the coast, made most careful search for fossils in the area south of the Gannel, but could only find numerous badly-preserved and silicified joints of crinoids, which are recognisable as far south as Holy Well. Most of them are so obscure that they can only be accepted as fossils from the occurrence with them of others slightly better preserved.

Penhale and Ligger Points show so much diturbance, with dips rising to 70°, 80°, and 95°, and shales passing into crush conglomerates, that we cannot be sure of the continuity until a larger area has been mapped. The wide tract of drifted sand between Penhale and Perranzabuloe also so masks the geology as to make it difficult to be sure of the relations between northern and southern areas. We seem to have a great thickness of grey more or less calcareous shales, probably quite 1000 feet, between the Old Red anticline and Perran Bay; but it is still doubtful whether the upward sequence is continued southward towards, and past, St. Agnes, or whether some big disturbance separates the two areas. The lithological changes in the killas of this part of Cornwall are too slight, and too much masked by shear-structures and metamorphism, for any exact correlation in the absence of clear sections or of characteristic fossils.

Mr. Ussher. The relation of the rocks just described to those of the south coast between Dartmouth and Fowey also remains to be fully cleared up; but Mr. Ussher has now been able to bring together the results of several years' work on the Devonian and Carboniferous rocks in the South Devon area. His account will be found in the Appendix.

## GRANITE.

Mr. J. B. Hill. The survey of the Carn Menelez granite has been pushed westward to the parish of Wendron. The lithological character of that granite have been described in former reports. It has also been pointed out that the mass is divided by a set of major joints, trending approximately E.N.E., which corresponds with an extensive system of fissuring. In this, according to Mr. Hill, both granite and slate have been involved, by the subterranean disturbances to which the former owes its origin and the latter its deformation. That system of fissures is parallel with the axis of granite intrusion; and also with the general trend of the elvan dykes and mineral lodes, both of which latter have taken advantage of the fissures for the introduction of the material that enters into their composition.

The progressive incoming of both these conditions, in conjunction with a progressive system of fissures, is illustrated by the nature of all these phenomena in the Carn Menelez mass.

Within that granite, in the Mabe and Constantine districts, mineral lodes and elvan dykes are practically absent, while the E.N.E. system of fissuring is almost entirely confined to the visible joints. The joint faces, however, frequently display slickensided surfaces, suggesting relative displacement of the walls, and they are sometimes seen to be small faults which have

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displaced the horizontal beds of granite to the extent of a few feet. Moreover the finer grained aplite veins tend to take a course parallel to these same joints. Mr. J. B. Hill.

In the parish of Wendron, which forms the central belt of the granite, this E.N.E. fissuring has been so sensibly increased that the stone which is quarried extensively in the two former parishes can no longer be profitably wrought. With this change, elvan dykes make their appearance; and an extremely attenuated set of mineral veins which have been extensively worked for tin. With the incoming of these conditions the granite, which is of coarse texture, is extensively veined by finer grained material.

The E.N.E. fissuring is no longer confined to the major joints, but the interspaces between these fissures are very closely fractured along parallel planes. Frequently they consist of tiny cracks which sever the various crystals along their course. In the next stage the cracks have been infilled with quartz, which has been followed by an introduction of schorl in association with, and finally to almost the total exclusion, of that mineral. With the oncoming of wider veins the rock takes on a banded appearance, the black schorlaceous bands standing out in sharp contrast to the granite matrix. The schorlaceous veins carry tin, and in some instances it is quite clear that the lode follows the E.N.E. joint. Over the whole district the schorlaceous bands rarely exceed a few inches in width and the lodes are correspondingly narrow. When the granite, however, is followed into the districts of Redruth and Camborne, the magnitudes of the fissures, lodes, and elvans have reached their maximum, and the marginal zones of that granite constitute the heart of the mineral area.

The mineral veins in the granite of the Wendron district are of two types—firstly, that in which the products have filled fissures by infiltration—and secondly, in which the granite itself has been partially or totally replaced by the process of metasomatis. In the latter process the first mineral to be attacked is usually biotite which has been converted into chlorite, while the replacement of felspar by quartz has followed. The final stage being reached when the product is a mixture of quartz, chlorite, and schorl, in which cassiterite plays a subordinate rôle. These two types of veinstone are however intimately related as the metasomatis of the granite is usually seen to proceed from the vicinity of small cracks or veins.

There are two masses of granite in the St. Agnes area; one at Cligga Head, the other to the west of St Agnes's Beacon. The Cligga Head mass is well exposed along the cliffs; but that near the beacon can only be seen in *situ* in two pits which were once worked for fireclay. Mr. J. B. Scrivenor.

The chief points to be noted in the Cligga Head granite are as follows:—

The joints are strongly developed, and towards the south are curved, first into an anticline, then a syncline, the southern limit of which rests on a wall of altered killas dipping at 60° to the north. To the north of the anticline they trend approximately 20° N. of E., and dip northward at about 60° N. (Both these dips are from the horizontal.) Perhaps these east and west joints would be better termed "bedding" in the granite,

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Mr. J. B. Scrivenor.

since, so far as can be seen, they lie parallel to the surface of the metamorphozed killas. A second series of divisional planes can be seen, but not very clearly, trending north and south. Two comby quartz veins, very clearly defined, have a similar direction; another trends parallel to the bedding.

The granite consists of white and rose-coloured orthoclase, sometimes in porphyritic crystals, biotite, and quartz, which inclines to crystal outline in some cases, and is further remarkable for containing included crystals, often orientated to the planes of the pyramids and prisms of the quartz, which by their form, and in some cases colour and absorption, can only be referred to tourmaline. The rock connot be called coarse-grained, but the porphyritic orthoclase crystals reach one inch. Owing no doubt to the small size of the bulk of the felspar crystals, there is no definite arrangement of them along the "bedding" planes. The biotite is deep brown, and transparent when fresh in thin cleavage plates. The axial figure is only typical.

The junction of the granite with the killas on the south is very clear. The killas has been converted into a compact brown tourmaline rock, and, owing to the presence of that peculiarly stable mineral and the elimination of felspar, which has probably contributed to the formation of the tourmaline, is actually more resistent to the denudation of the sea than the granite itself; so that a bold cliff of altered killas projects beyond the granite to the west for some distance. It must be particularly noted, however, that it does not rise above the granite, so as to form a feature inland.

The junction on the north is vertical, as can be well seen in the cliff section facing in that direction. This vertical junction gave rise to a supposition, quoted by De la Beche, on the part of miners, that the granite had been intruded as a big dyke; but from later evidence, obtained from a Mine Report dated 1857 and 1858, there can be no doubt that this is a faulted junction and that the main mass of the granite, which is the faulted portion, has been lowered at least 300ft. The fault, then, is one of the great cross-courses, but differs in this point—that the downthrow has been vertical and not complicated by any appreciable horizontal movement. The fault does not affect the whole of the eastern outcrop of the granite, but only the northern part; that part should then be looked on as part of the main mass; while the southern part, as can be seen both by the form of the "bedding" and the nature of the islets in the sea to the west, is a short apophysis intruded horizontally into the surrounding killas.

Near the south junction the granite is modified: small veins of orthoclase, of quartz, and of large thin crystals of biotite, as much as $\frac{1}{2}$in. in diameter, are frequent.

The most interesting point however in the petrology of this mass is the metasomatism along the "bedding" planes, resulting in the production of a band of greisen on either side of the fissure, which is itself filled by a quartz vein, generally rich in wolfram and tin, with some mispickel and basic sulphate of copper derived probably from copper pyrites. The "bedding" planes are not a great distance apart and the greisen extends in some cases several inches from the quartz vein, so that the cliff

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presents a peculiar striped appearance. Actual measurements of some of the greisen bands from side to side, and of the unaltered granite in between, give these results:— Mr. J. B. Scrivenor.

| Greisen. | Granite. |
|---|---|
| 20 in. | 3 in. |
| 6 „ | 5 „ |
| 9 „ | 20 „ (N. part of mass only.) |

The greisen bands are frequently less than the above. None greater than twenty inches were measured.

There is no alteration along the north and south joints.

Although the bands of greisen in the cliff section are well defined, the passage from granite to greisen is seen to be gradual in the microscopic section, the change being marked by the gradual disappearance of the orthoclase, which is replaced by secondary silica and muscovite. The form of the original felspar crystals can often be clearly made out in the greisen. In the granite the orthoclase is never fresh; not only is it turbid with kaolin, but secondary muscovite and silica are present to a greater or less extent. The biotite too, is not perfectly fresh: near the greisen bands it is almost completely bleached, with a faint trace of vandyke brown. The absorption is strong — vandyke brown — colourless. It contains some titanium, as is shown by the presence of crystals of rutite: these, however, are not common. Tourmaline is abundant as ragged brown and blue crystals. It frequently contains included zircons and dark grains which are indeterminable; both of these are surrounded by well-marked pleochroic halos. In many cases, if not all, the tourmaline has taken the place of the biotite, both in the greisen and in the granite near its junction with the former.

The greisen contains quartz of two generations; the original quartz of the granite with orientated tourmaline crystals and occasional minute zircons and very good fluid cavities; and secondary quartz derived from the felspar and mica, without orientated inclusions, but easy to distinguish from the original quartz, not only by the smaller size of the individual grains, but also by the greater abundance, though more minute dimensions, of the fluid cavities. A little of the original biotite is left, almost completely bleached, but showing strong pleochroic halos; the bulk of it has been replaced by tourmaline. Cassiterite is not uncommon: a portion of the rock crushed to powder and separated in cadmium borotungstate yielded a considerable quantity. The mica is chiefly muscovite; but another occurs in small nests not derived from the felspar, with brilliant polarizing tints, but colourless. Owing, however, to the difficulty of separating this with certainty in heavy liquids from the muscovite, it is impossible to determine its exact nature; seeing that lepidolite occurs coating the sides of the fissures nearer the junction with the killas to the south, it may be that this also is lepidolite; or again, it may be gilbertite, a mica hard to separate as a distinct species from muscovite. Gilbertite is mentioned by Dr. C. Le Neve Foster as occurring at Cligga Head. Lastly, topaz, in irregular colourless grains, rarely seen with crystal outlines or cleavage, is abundant throughout the greisen bands.

Near the junction with the killas to the south, the greisen bands become more frequent and thinner. Sometimes they cannot be recognised along the "bedding" planes, which, independently of the presence or otherwise of the greisen, are frequently coated with crystals of lepidolite, pink orthoclase, colourless topaz, wolfram, and cassiterite, the usual vein of quartz being absent. One specimen was collected of a joint face coated with a continuous mass of topaz crystals, which might be easily passed over as quartz.

Whatever may have been the medium, whether vaporous or fluid, which caused the metasomatism of the granite, it is evident that it must have been rich in boron and fluorine.



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Mr. J. B. Scrivenor.

The St. Agnes is much less satisfactory than the Cligga mass. The two exposures mentioned above are very poor and show no fresh granite, but greisen similar to that at Cligga Head. However, a considerable quantity of rock showing the original felspar, sometimes fairly fresh, has been brought up from the old Bungay Lode and dumped by the shaft. Of the structure of the whole mass nothing can be said; but petrologically there is a close parallel with the Cligga mass, except that as a whole it is more coarse-grained, and the quartz has even a greater tendency to develop crystal boundaries. The porphyritic orthoclase crystals are more numerous. Their colour, too, is white and rose. Topaz occurs in the greisen, as at Cligga. Veins of fine-grained granite with abundant muscovite can be seen traversing the killas in the big open work at Wheal Coates. In the greisens the felspar pseudomorphs are often of a dull green or brown colour.

ELVANS.

The elvans of St. Agnes and Perranporth are remarkable for the regularity of their strike, which is roughly 20° N. of E. There are two principal dykes, the St. Agnes elvan and the Perranporth Granitic elvan.

The St. Agnes elvan is first seen in the cliff south of St. Agnes Head, whence it can be traced to a point between Newdowns Head and Trevaunance Coombe. There it disappears under the sea, to reappear between Trevellas Coombe and Green Island. Along the cliff as far as Hanover Cove it is excellently exposed, but after this the strike takes it inland, where the evidence is not so satisfactory. It can be traced along a gulley leading from the dynamite factory to Perran Coombe, where a good section occurs in the new railway cutting. From here to the old minerals railway it can be seen in three spots; and since in the cutting on the minerals railway it does not reach the surface of the killas, it is probable that the bad evidence elsewhere is partly due to that cause. Near Newlyn fragments in ploughed fields probably belong to the same elvan.

There are some interesting points to be noticed in the composition of the elvan. At St. Agnes Head it is a light-coloured quartz-porphyry, the phenocrysts of quartz and orthoclase not being large. Apparently it retains this character as far as Bawden; but in the big quarry on the edge of the cliff east of that cottage it is of quite a different character. The matrix is dull grey with rosettes of tourmaline. Small grains of quartz are frequent and kaolinized crystals of felspar are dotted in irregular groups without any relation to the distance from the margin. They reach half an inch in length. It is remarkable that these crystals only appear near the granite masses. Casts of similar crystals occur in greater profusion near Cligga Head, on Wheal Prudence.

There is one very interesting point in connection with the elvan north of St. Agnes Beacon, *i.e.* by "White Rocks" a piece of greisen is shown caught up by the elvan on its intrusion.

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On its reappearance N.E. of Trevellas Coombe the dyke has the character of an ordinary quartz-porphyry with tourmaline, which is maintained as far as Scotland Farm at least. In the sections on the old minerals railway it presents a new form. Mica is present in small quantities, and the structure of the core of the elvan is that of a very fine microgranite, the mica only being prominent as a phenocryst. At the margin, however, occasional prophyritic crystals of quartz and felspar occur, and a flow structure, resulting in a fine cleavage parallel to the walls of the dyke, is well shown. The section on the east of the rail shows the upper limit of the elvan: here the flow structure is beautifully preserved. The fragments in the fields by Newlyn are those of the ordinary type of quartz-porphyry. The cooled margin is generally about 4 inches thick. Mr. J. B. Scrivenor.

The dip of the St. Agnes elvan is variable. North of the Beacon and so far as Wheal Prudence it is dipping north at 50° to 60°. East of Wheal Prudence it gradually becomes vertical and in the railway cutting at Perran Coombe it dips south at an angle of 30°. In the quarry north of Goonhavern it is again dipping north. In the minerals railway the dip is 35° north in the west section. In the east section it is obscure.

In marked contrast to the St. Agnes elvan, the Perranporth granitic elvan is curiously persistent in petrological characters It also can be traced as far as the old minerals railway, where the dip is seen to be 45° south. Elsewhere, unfortunately, the dip cannot be seen. The rock is a microgranite, but the margins take on the characters of an ordinary quartz-porphyry. An occasional porphyritic crystal of orthoclase is seen in the mass, but as a whole the rock is remarkable for the uniform size of the grains. The jointing in both these elvans is very irregular.

Several other elvan dykes have been traced in the region between St. Agnes and Newquay; as, however, they vary but little in lithological character, a description of them will be reserved till the area towards which they tend to converge has been examined. Mr. Reid.

## GREENSTONE.

The much-sheared greenstone of Kelsey Head has long been known; but it is interesting to discover similar thin sills at several points along the same line of strike in the calcareous shales. The small masses are greatly altered by shearing, mineralization, and weathering. Another mass of greenstone occurs, however, in the middle of the sand-dunes, where it seems to have been overlooked, though it is close to the overwhelmed church of St. Piran. This greenstone is much fresher than elsewhere in this area; but being surrounded by sand-drift its exact relation to the killas cannot clearly be made out. It is a much-sheared rock, in mass and hand specimens closely resembling some of the sheared greenstones of Chyandour, near Penzance. It is remarkable for having joint-surfaces covered with crystals of axinite and epidote, and for Mr. Reid and Mr. Scrivenor.



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Mr. Reid and Mr. Scrivenor.

being associated in some way with masses of ironstone containing garnets, both at this point in the neighbouring ironstone mines. Neither the greenstone nor the associated killas show any metamorphic spotting and the locality seems to be fully three-quarters of a mile outside the metamorphic aureole. A fuller petrological examination will be made.

## MICA TRAP.

Mr. Reid.

A group of small dykes of Mica Trap or Minnette form a noticeable feature between Newquay and Holywell Bay, and traces of a similar rock have been met with near St. Allen, connecting the Newquay outcrops with those near Falmouth. The behaviour of these dykes is very different from that of the elvans; instead of following straight lines of fracture they zig-zag irregularly along joint-planes in the killas, widening and narrowing very abruptly. As a rule the rock is much decomposed; but a quarry on the north shore of the Gannel is now being worked down to the water-level for road-metal, and has yielded stone better preserved than any that has previously been obtained in Cornwall. Some slides of this rock were prepared last summer by Mr. Barnes and from them Mr. Scrivenor has drawn up the following description:—

Mr. Scrivenor.

The rock is of fairly uniform grain, and panidiomorphic; but the felspar tends to form a ground mass. This felspar is orthoclase, sometimes well-preserved. There is no reason to suspect the presence of a plagioclase felspar. The ferromagnesian constituents are: biotite, largely altered to chlorite, epidote, and magnetite: calcite also appears in association with this mineral; colourless augite, in short idiomorphic prisms, and brown hornblende, twinned parallel to 100, sometimes polysthenically. A little insterstitial quartz and calcite occurs, and some apatite. The amount of hornblende and augite varies considerably in different specimens. One section shows an enclosed mass of granitic quartz and orthoclase, the former with a well-marked reaction rim. The rock is remarkable for the presence of three ferromagnesian minerals, and, according to Rosenbusch, must be called an augite-hornblende-minette.

## METAMORPHISM.

The metamorphism caused by the granite masses is better seen in the case of the Cligga Head granite than the St. Agnes mass. An aureole was mapped in both areas; but it must be remarked that owing to the peculiarly sporadic nature of the spotting at a distance of about one mile from the contact, such a line is extremely vague. In the case of the Cligga granite, however, the aureole may be said to be fairly well defined. Walking south-west along the Perran Sands, one first encounters spotting near the Wheal Vlow adit. Until the bay immediately west of B.M. 269.8 on the sand-hills is reached, it is very sporadic and easily passed over; in that bay, however, the spots become more defined and more numerous. So far there has been no other evidence of metamorphism. On crossing the stream to the Chapel Rock and the cliffs adjacent however, not only are the spots found to have increased both in size and number, but a general bleaching of the shales and mud-

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stones have set in. Still the dark and light bands of the mudstones may be made out; but in the case of the Portscatho it is already hard to distinguish the thin shale bands, a difficulty which increases as one approaches the granite; indeed, were it not for a portion of the killas at Wheal Prudence being silicified, thereby revealing again its composition, it would be hard to recognise this pale altered mass as the Portscatho Series. It was found, however, that careful examination enabled one to identify the original shale bands. Some of this bleached killas with strong spotting was powdered for microscopical examination, but no secondary minerals were found; nor do the spots develop into any mineral in this aureole. Definite tourmaline rock was seen first between the Shag Rock and the boundary of the dynamite factory; between these and the actual junction it does not occur again. Spotting and bleaching of varying intensity are developed in all the killas *débris* on the dynamite factory. The projecting cliff at the south junction affords as good an example of tourmalinization as could be desired. It does not appear to extend more than a few feet, giving place to the same phenomena of spotting and bleaching observed on the other side. Mr. Scrivenor.

It will be observed from the relation of the form of the aureole to the existing mass that there must be a considerably greater mass now covered by the sea and extending toward the north-east.

In the St. Agnes aureole the spotting is as greatly developed as in the Cligga aureole; but the bleaching is not so marked, the killas being of light shades of red, yellow, and grey, besides being indurated slightly. At two localities, bodies, evidently due to the proximity of the granite, were found which resemble chiastolite, but which do not hold out any hopes of certainty.

The elvans, with one exception, produce nothing more than a slight hardening macroscopically; microscopically, a section, from an elvan in Mr. Reid's ground, shows small prisms of indigo-blue tourmaline and muscovite, which may or may not be secondary. (Gravel Hill elvan, Perran Sands.)

The exception is in the big quarry on the cliff near Bawden Cottage at St. Agnes. Here a piece of brown tourmalinized killas was found at the junction. The tourmalinization did not appear to extend beyond half an inch, although no doubt a microscope section would reveal a much greater limit.

A mica-trap at Towan Head, Newquay, although more basic, and therefore it may be reasonably presumed, injected at a lower temperature, has had the effect of altering the Newquay shales in such a way as to resemble those altered tuffs known as "Hälleflinta." The alteration extends several inches from the margin of the dyke; this may be explained, however, by the fact that the dyke has many ramifications.

## QUARRIES.

The parts of Cornwall examined in 1902 only supply road-metal and building stone for the immediate neighbourhoods. Mr. Reid.

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Mr. Reid. Most of the elvan dykes have been worked for road-metal, and also for building-stone; which has been a good deal used in Newquay; though the hard flat-bedded killas is generally preferred. The elvan used for building is commonly the buff weathered rock near the surface, the harder and tougher grey rock usually occurring lower down, being only reached in a few of the quarries. Some of the much altered and silicified elvan is very tough close to the surface and makes good road-metal; though the main roads around Newquay are metalled with a highly-altered killas from the metamorphic area near the granite margin at Roche.

## MINING.

Mr. J. B. Hill. Although the districts surveyed have formerly been the seat of extensive mining industries, few of the mines are at present active. Tin is still profitably mined at St. Agnes, and trials are being made for silver-lead and ironstone in a few other places. In the valley between Redruth and Carn Brea the washings from the mines are extensively treated by modern machinery and large quantities of tin recovered that would otherwise find its way to the sea; and works on a smaller scale are active in the valley at Bissoe. Tin streaming in the original sense of the term is practically a thing of the past, but an occasional tinner may still be seen working over the old stream works on Porkellis Moors. In the same neighbourhood the old lodes are occasionally worked on a small scale. At the present moment Wheal Enys near Porkellis is being profitably worked by two miners at a depth of 12 fathoms, where a string 8 inches in width carries tinstone estimated at 3 cwt. to the ton.

In the last few years the *débris* from the mine burrows has been put under the stamps, more especially from those mines that were originally worked for copper, in which the tin ore was neglected. In the Bissoe valley, at Twelve Heads, the materials from such burrows are at present being stamped. The burrows from the United mines in that district have been recently worked on a large scale, but unfortunately these operations have had to be discontinued.

The ochre works in the Bissoe Valley have been in continuous operation for upwards of forty years. The main county adit discharges into the stream above Bissoe, and the oxide of iron carried in suspension, after being collected in pools, is pulverized, washed and dried, producing a fine brown ochre.

In the same locality works exist for the refinement of arsenic, the crude material which is calcined at the mines and recovered in flues being sent thither for final treatment.

Mr. MacAlister, who joined the service at the end of April has been engaged for the greater part of the season in the laborious task of reducing the mining information from the working plans to the survey maps. These duties have been undertaken at Camborne, Truro, and the Home Office in London. At Camborne he has been largely indebted to the authorities at Dolcoath,

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who have placed office accommodation and all facilities for the work at his disposal. To Messrs. Henderson & Sons, of Truro, the survey is under a similar obligation, while at the Home Office he has been indebted to Mr. W. W. Ware, of the Mining Record Department, for valuable assistance in the prosecution of the work. Mr. J. B. Hill.

The reduction of the mining plans, referring to sheet 352, which includes the Camborne and Redruth districts forming the heart of the Cornish mining region, is now well advanced; while considerable progress has been made with the Land's End sheet to the westward (351).

For the last two months of the year, Mr. MacAlister was engaged in the examination of the mineral district of Camborne, but more particularly in the investigation of the lodes of Dolcoath, and of the Great Flat lode, which may be said to constitute the type lodes of that area. Mr. MacAlister.

The relation of the mineral lodes to the granite and killas of the Camborne area will be seen by reference to the accompanying diagram.

The study of the mining plans shows the upper surface of the granite to be a gentle dome, occasionally broken by horizontal furrows or ridges.

The lodes, which are usually steeply inclined, traverse both killas and granite alike, but the mining in the area is mainly confined to the raising of stanniferous ore from the deeper portions of the lodes that lie within the granite.

Underground investigations, combined with examination of the plans, afford very limited information of the subterranean courses of the elvans. They appear, however, to be patchy and discontinuous, and of variable dip, and more frequently hade to the north than to the south.

It is noteworthy that a part of the outer belt of the granite for a thickness of about 150 feet, in the neighbourhood of the Great Flat lode, is much decomposed, notwithstanding its depth from the surface. The decomposed material is largely kaolinized, and is also schorlaceous.

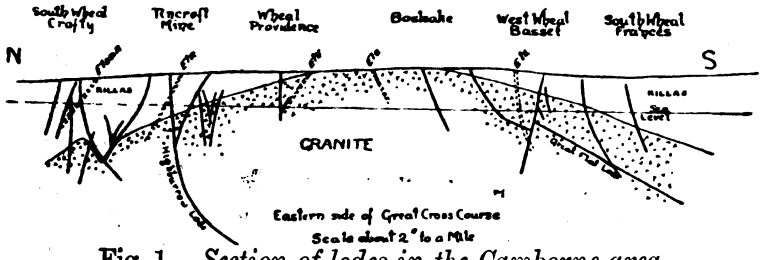


Fig. 1.—*Section of lodes in the Camborne area.*

The lodes, which trend approximately E.N.E., are crossed by a system of N.N.W. faults, which displace the killas, granite, elvans, and lodes. A noteworthy feature is the tendency for the lodes of the Camborne area to curve towards the south, in depth, notwithstanding that their upper extensions may hade to the north (see diagram). In marked contrast to the usual high,

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Mr. Mac-Alister. prevailing dip is the low hade of the Great Flat lode; in its easterly extension, however, it appears to revert to a normally inclined lode, in Wheal Uny.

The Dolcoath group of lodes shows a marked tendency to branch in an upward direction, so that the main trunk occurs at depth; and this group hades steeply to the southward. Their walls are by no means sharply defined, but the hanging wall is the most definite. The lodes occasionally divide and re-unite again at depth. The enclosing rock, or "horse," may be of great magnitude; at Dolcoath a "horse" occurs 240 feet in length, the depth of which has not yet been definitely ascertained. It is considerably impregnated with cassiterite, usually in the form of minute strings.

The well known disposition for the ore to occur in concentrated patches along the lode, known as "bunches," is further characterised by the tendency of these bunches to assume a general easterly hade, oblique to the trend of the lodes in which they lie, and a series of bunches in one lode has its counterpart in adjoining lodes.

The N.N.W. fault, locally known as the Great Cross Course, heaves the Dolcoath main lode 74 fathoms, while a mile further to the south it heaves the Great Flat lode but a few fathoms. It would appear, therefore, not to be a simple vertical displacement, but that it involved a tilt from the horizontal, which varied on either side of the fissure.

In the appendix (p. 154), Dr. J. S. Flett has described the microscopic characters of the ores.

## 4. South Wales District. Glamorganshire and Carmarthenshire.

Mr. Aubrey Strahan, M.A., District Geologist.
Mr. B. S. N. Wilkinson.
Mr. T. C. Cantrill, B. Sc.
Mr. E. E. L. Dixon, B. Sc.
Mr. H. H. Thomas, B. A.
} Geologists.

Mr. Strahan. The work of the past year has lain between Llandilo and Carmarthen, in the north, and around Cross Hands, Llannon, Llangennech, Llanelly and Pembrey in the coalfield.

The surveying of the Ordovician and Silurian rocks and Old Red Sandstone on the north side of the Carboniferous area has been continued by Mr. Thomas and in part by Mr. Cantrill; that of the northern part of the Carboniferous area, including the North Crop of the coalfield by Mr. Cantrill; the central part of the coalfield by Mr. Dixon, and the southern part by Mr. Strahan. Mr. Wilkinson was engaged, after the completion of Gower, in a tract lying west of the coalfield.

### Ordovician.

Mr. Cantrill and Mr. Thomas. A brief examination of some rocks at Maes-y-falien, which appeared to overlie Llandilo Flags, has shewn the existence of inversion; the doubtful strata being in reality the Ffairfach Grit

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and *Didymograptus-bifidus* shales emerging from beneath the Llandilo Flags. From his work upon these rocks westwards along the Vale of Towy Mr. Thomas has been able to furnish the following remarks, the subdivisions being in ascending order:— Mr. Thomas.

The *Didymograptus bifidus*-beds maintain their character as black shales and sandstones. They are probably in contact with the Silurian rocks almost as far west as Llanarthney, and are poorly exposed at Troed-y-rhiwgoch, but for the most part are concealed by drift.

The *Ffairfach Grit* appears to be truncated westwards by an offshoot of the fault which forms the Silurian boundary. The Llandilo beds which form the southern limb of the Llandilo anticline all in turn run obliquely up to this fault, and so far have been seen no more on the south side of the Towy.

The *Llandilo Flags* on the north side of the Towy pass up into some unfossiliferous shales; traced westwards they pass horizontally also into shales, with less frequent limestones—at the same time brachiopods become less common, but graptolites of the type of *Didymograptus Murchisoni* begin to abound.

The *Dicranograptus*-Shales appear to be represented by some black shales with thin cherty or gritty bands, which are faulted against Llandilo beds near Dryslwyn and Cilsân, but which have yielded no fossils.

A series of pebbly grits, conglomerates and mudstones comes in west of Llanarthney, and locally contains Tremadoc trilobites. The rocks have been thrown into a series of east and west folds and are probably also much faulted.

### SILURIAN.

The lowest Silurian rocks seen in the valley of the Cîb, though resembling the Wenlock mudstones, contain some Upper Llandovery forms, such as *Pentamerus undatus*, *Petraia*, etc. Above them comes a great mass of greenish mudstones at the base of which Tarannon Shales may possibly be represented. Mr. Cantrill.

The whole of the Silurian group is truncated by the Old Red Sandstone westwards. The upper part, which becomes increasingly sandy westwards, is the first to go, and the Lletty Grit follows, leaving only some mudstones with *Atrypa reticularis* etc. Lastly these also disappear about a mile west of Middleton Hall. The truncation may be attributed in this case possibly to unconformable overlap. There is reason to think that the lower members of the Old Red Sandstone are themselves overlapped by higher members, as were the Tilestones further east. Mr. Thomas.

### OLD RED SANDSTONE.

The lowest member of the Old Red Sandstone consists of fissile sandstones and marls, with a prevailing green tint, due apparently to the presence of chlorite which can be recognised sometimes in large quantities. They are about 450 feet thick and are followed by the great mass of marls with dull-red sandstones which constitutes the bulk of the lower sub-division of the Old Red Sandstone. Mr. Thomas.

Above the marls come the Brownstones, in which it is possible to distinguish the highly micaceous green and red sandstones and marls of the Senni Beds, though there is no break between Mr. Cantrill and Mr. Thomas.

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Mr. Cantrill and Mr. Thomas. them and the beds above or below. Though sandstones are subordinate to marls, the Brownstones form a bold escarpment south of the Gwendraeth Fach.

The uppermost member consists of about 150 feet of pebbly sandstone with bright-red marls. Though generally red the sandstones often have a yellowish or olive-green tint, especially towards their top where they pass up into the Carboniferous rocks.

Mr. Wilkinson. The Old Red Sandstone of Pendine and Laugharne consists in the main of marls with a poor representation of the Brownstones. The topmost beds consist of pale-green micaceous flags which pass up into the Carboniferous Limestone, the conspicuous conglomerates of Gower being absent. The marls contain grits and some compact cornstones; many of them are honeycombed by the cavities left by the weathering out of calcareous concretions.

A large part of the series is admirably laid open to examination in the cliff between Llanstephan and the Tâf. Here also may be seen a great disturbance which descends the Gwendraeth Valley and passes Llanstephan in a W.S.W. direction across the promontory. Parallel to it, half a mile further south, there is a small anticline accompanied by some small overthrusting. North of the disturbance the Old Red Sandstone rises northward in gentle undulations.

In Gower, the examination of which was completed during the past year, it was found that the uppermost white conglomerates are probably present in Rhossili Hill, though they are not visible. The base of the marls almost certainly lies below sea-level, making it certain that there is a great mass of the lower Old Red sub-division present in Rhossili Hill which is absent in Cefn-y-bryn. Some small excavations on Cefn-y-bryn, made in the hope of exposing the base of the Old Red Sandstone, led to no definite result beyond showing that the junction with the Silurian Rocks is sharp.

## CARBONIFEROUS.

### *Carboniferous Limestone.*

Mr. Cantrill and Mr. Thomas. The Lower Limestone Shales are visible in one place only in the main escarpment, namely, at Banc-y-mansel, but are exposed in a faulted outlier at Bryn-yr-odin, which is referred to later on. They may be about 30 or 40 feet thick.

The lower half of the Main Limestone consists in part of dark oolite. It forms a bold escarpment and has been much quarried. The light-coloured oolite above it continues but is less distinct, while the sandstone which ran at its base has disappeared. Upon the light oolite there rests a bed of yellow and red marl about 30 feet thick, which may be compared with a stratum resting on a white oolite in Monmouthshire.* It contains lumps of

* Geology of the Country around Abergavenny, pp. 23-25 (1900).

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oolite and crinoidal limestone near its base. The limestone above is dark and cherty, and occasionally oolitic. Mr. Cantrill and Mr. Thomas.

The Rottenstones are poorly exposed near Banc-y-mansel and at Garn. The decomposed cherts have been worked for plastic clay near Gareg Gwenlas and Garn.

In Gower the Lower Limestone Shales are shown in a nearly vertical position near Rhossili where they are faulted against Old Red Sandstone. They consist of fine shale with thin bands of limestone, which sometimes pass into rottenstone, as at Pitton Mill. Dolomitisation along bedding-planes is particularly well exhibited at Overton Mere, near Port Eynon. The outlier of limestone at Black Rocks, west of Llanstephan, consists of dark-blue limestones with grey shales, all belonging to the Lower Limestone Shales; they lie nearly horizontally upon greenish micaceous sandstones, but the junction is concealed. The more massive limestones have been burnt for lime. A second outlier at Honey Cors Farm, south-west of Laugharne, consists of massive blue and light-grey limestones, which are largely quarried for burning and road-metal; the Lower Limestone Shales, if present, must be represented by limestones. Mr. Wilkinson.

At Pendine, a natural passage can be followed up from the Old Red Sandstone into the Lower Limestone Shales, which resume their normal aspect. The Main Limestone, consisting of evenly-bedded, often massive, blue limestones, forms a bold cliff west of Pendine.

Immediately to the west of Dolwen Point there occurs a remarkable conglomerate in the limestone, the sequence of strata being as follows:— Mr. Strahan.

*At Pendine Steps.*

Even-bedded, black limestone, in beds of 1 to 3 feet thickness; the base undulating so as to fill up inequalities in the underlying surface, the top straight.

Lumps of black compact limestone imbedded in a granular calcareous matrix, with some lenticular seams of yellow calcareous sand passing down into

Yellow calcareous rock containing large and small lumps of various kinds of limestone, some red, some coarsely crystalline, some oolitic. In places the rock is laminated; in others it contains harder bands which are disturbed and broken, and which are truncated by the black limestone above, as though by an unconformity. Much of the rock has a gravelly aspect, and in its upper part there is some fine gravelly conglomerate full of well-rolled limestone fragments.

Massive light-coloured limestone of saccharoid texture.

The thickness of the conglomeratic series amounts to about ten feet, but its base is ill defined, owing to the breaking up of the surface of the massive limestone below it.

The folding and breaking up of parts of the yellow rock suggest, at first sight, subsequent movement, but the abundance of well water-worn fragments of limestone, and the manner in which the overlying limestone adjusts itself to the uneven surface on which it was deposited, proves the contemporaneous age of the structure.

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### *Millstone Grit.*

Mr. Cantrill and Mr. Thomas. In the North Crop the Millstone Grit presents the same features as heretofore except that there appear to be several shale bands interbedded with the basal grits. Upwards the subdivision passes into the Coal Measures, and the Farewell Rock having lost its massive character, the dividing line between the two becomes most indefinite. Generally the sandstones near the top of the Millstone Grit are hard and olive-green, the highest occasionally becoming a quartz-grit, but similar rocks recur at higher horizons, in what must be considered Coal Measures.

The basal grit of this region is devoid of pebbles, and has been dug for "silica sand" wherever it is sufficiently rotten. The aspect of the shales which constitute the middle member of the Millstone Grit has led to useless trials for coal or mine.

Mr. Strahan. The finest exhibition of the Millstone Grit in this region occurs at Ragwen Point, near Pendine. It shows a return to the Monmouthshire type, but differs totally from that observable at Bishopstone in Gower.* The grit rests upon a thin-bedded limestone with chert, and with numerous partings of shale, much resembling the "black lias" of Oystermouth. About 80 feet of grits and shales are exposed, the latter occurring in three bands, each of which make a ledge in the cliff. Septaria of smooth black limestone with *Lingula*, and calcareous or pyritous bands occur in the shales, but the fossils observed in Monmouthshire† were not detected. Some of the grits are coarse and contain small pebbles.

### *Coal Measures.*

An account of the part of the coal-field which has been examined during the past year will be found in Appendix IV., p. 170. The area includes the neighbourhoods of Llanelly, Pembrey, Llannon, Cross Hands and Pontyberem. Among the questions which have arisen for solution may be mentioned the existence of a series of great easterly downthrows along the coast, and of westerly downthrows along the North Crop; the existence of some remarkable structures ranging south-westwards from Ammanford, in which over-thrusting is prominent; and lastly, the continuance of the Llanelly syncline under the foreshore westwards, and the limit of the areas occupied by the seams which have yielded the bulk of the coal near Swansea and Llanelly.

#### FAULTS AND DISTURBANCES.

Mr. Thomas. The general west-south-west strike of the Silurian and Ordovician rocks continues through most of the area examined during the past year, but is curiously deflected near Nelson's Tower (Middleton Hall). Swinging first to W. 20° N., it then

* Summary of Progress for 1900, p. 87.
† Geology of the Country around Abergavenny, p. 47, 1900.

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resumes its normal direction, making a curve about a mile and a half in length, and convex to the north. Thence to the western edge of Sheet 230, the strike runs W. 30° S. The lower beds of the Old Red Sandstone follow this curve, but the upper beds and the Carboniferous Limestone hold to a constant strike of W. 15°–20° S. The principal faults, as before, follow the strike, but some few cut across it approximately at right angles. The lower limit of the Silurian outcrop, which we believe to be a fault throughout Sheet 230, is visible at Arbont, near Middleton Hall. Mr. Thomas.

A big fault associated with a crush-conglomerate makes itself evident near Aberglasney in the parish of Llangathen. Passing the farm called Grongar East, it cuts through the hill (Grongar) and probably proceeds to the north of Dryslwyn Castle, where Llandilo Flags and limestones are faulted against higher shales. What is evidently the same disturbance is indicated near Llangathen by De la Beche and Ramsay on Horizon Section, Sheet iii, Sect. No. 2. It is interesting to note that this line of crush runs more or less parallel with the western part of the curve in the strike of the Silurian rocks described above.

The rocks to the west of Llanarthney are much folded. In a series of anticlines and synclines, each anticline presents a steep dip to the south and a gentle dip to the north. The steep side, there is reason to think, is often replaced by a fault or thrust bringing up older rocks, but the unravelling of the detailed structure must wait the examination of the country further west.

The configuration of the ground in the middle of the outcrop of the Old Red Sandstone north-west of Carmel led to the anticipation that there must be here a disturbance of considerable magnitude. Among a number of strike-features a depression, formerly occupied by a *pysgodlyn* or fish-pond, at once attracted attention by its depth. Followed westwards it led to Bryn-yr-odin, where the existence of a great disturbance was obvious, for an outlier of Carboniferous Limestone occurred in what appeared to be a most anomalous position.

The structure presents a close similarity to that of Castell Cennen, where also a mass of limestone has been thrown in far below the main escarpment. The fact that the Old Red Sandstone between the outlier and the escarpment dips uniformly southwards at a high angle, makes it certain that the displacement by which the limestone was dropped in must have been enormous. The fracture is visible, and in part of its course, if not everywhere, is compound, for a strip of Old Red Sandstone is wedged in along it between two strips of limestone, while much of the limestone is in a more or less pulverised condition. The northern boundary of the outlier is also a fault. The limestone extends along the belt of disturbance for about a mile and a quarter only, but the depression which characterises the belt continues and leads us to Porth-y-rhyd, where again view may be obtained of the smashed strata to which the depression is due. Thence it ranges down the Gwendraeth-fach across a tract which has not yet been examined.

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Mr. Strahan.

Near Llandyfaelog the Gwendraeth-fach enters the ground surveyed by Mr. Wilkinson, and was found in accordance with anticipation to follow the line of disturbance. A third outlier of limestone was detected here by Mr. Wilkinson, holding the same relative position to the main escarpment and to the Old Red Sandstone as those of Castell Cennen and Bryn-yr-odin. On its south side the limestone is certainly faulted, on its north side probably so, and the evidence for a huge displacement in the southern fault is no less conclusive than in the other cases. It is to be noted, however, that the Gwendraeth, after following the line of disturbance for some miles, leaves it just where the outlier of limestone commences, an unusual circumstance for which explanation will be sought. West of the outlier the course of the disturbance is indicated by a slight depression past Llandyfaelog, but a short distance further on it catches the local drainage and has been eroded into a deep ravine, which continues past Iscoed to the shore of the Carmarthen estuary. The bottom of the ravine shows marls and Brownstones in an intensely broken state.

On the same line, prolonged across the estuary, we get evidence of a disturbance at Llanstephan Castle, and finally a clear view of it on the west side of the Llanstephan promontory. Here the disturbance seems to have passed into a monocline without fracture. The marls with cornstones which form the southern part of the promontory roll down northwards at a high angle and pass out of sight. Higher beds of the Old Red Sandstone come in above, with a gradually decreasing dip, and eventually nearly horizontal Carboniferous Limestone appears in the top of the cliff at Black Rocks. A gentle anticline runs parallel to the disturbance, but a few hundred yards south of it, and some small overthrusting is well laid open to view in the cliff. One such fracture, 300 yards south of St. Anthony's Cottage, slopes gently southwards; the beds above the fracture have been pushed up a few feet northwards, relatively to the beds below.

The course of this disturbance along the middle of the outcrop of the Old Red Sandstone for so many miles, its effect in throwing in patches of limestone by what must be an enormous displacement, and lastly the guiding influence which it has exercised upon the rivers, in common with other disturbances of the E.N.E. and W.S.W. system, all combine to give it an unusual interest.

Continuing across the outcrops southwards from the disturbance last mentioned we reach the northernmost of the series of overthrusts which have been proved in working the anthracitic coals. The details are given on p. 184, but we may here recapitulate the main facts, that they run in a general E.N.E. and W.S.W. direction; that the fractures, though sometimes nearly vertical, all hade to the south and lastly that they have the effect of throwing the strata down northwards and of repeating the outcrops. Three stages in the formation of a complete overthrust can be recognised, namely, the simple monocline or roll down to the north, the monocline accompanied by inversion,

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and lastly the overthrust, which may be regarded as a monocline in which folding has been supplemented or replaced by fracture and displacement. Mr. Strahan.

It is worthy of note that these and the Gwendraeth Valley disturbance differ from the folds in the old rocks near Llanarthney (p. 45), in the fact that they throw the strata down northwards. Those folds, on the other hand, may be regarded as a series of monoclines by each of which the strata are rolled down southwards. An explanation may be found in the fact that the two sets of disturbances lie on opposite sides of a great anticline.

The tracing of these lines of disturbance through the Pennant region has proved a matter of great difficulty, but one at least is clearly indicated near Llannon (p. 184), and what may be the same passes south of Horeb into country not yet examined. Here again the fracture-plane slopes to the south, and the rock above it has been pushed northwards relatively to that below.

The Llanelly syncline runs almost due east and west, and both in this fact and in position is linked rather with the pre-Triassic system of South Carmarthenshire and Glamorganshire than with the E.N.E. system which commences in the Vale of Neath. The structure, as shown by the section forming Fig. 2, includes an overthrust, which "dips" southwards, like those described above.

In the limestone of Gower small overthrusts are far from uncommon. One which runs E.S.E. just below the entrance to Mitchin Hole, traverses limestone which dips south, and hades in the same direction, but at a slightly steeper angle than the beds. It is particularly interesting to find that a N.N.W. fault, to which the cave and the gully leading to it owe their existence, shifts the thrust-plane. Another which occurs 500 yards east of Black Grit contains a "spar," which testifies to the energy of the movement even in these subsidiary fractures. A specimen of the "spar" is thus described by Dr. Flett:—

E. 3626. Mylonised limestone. A grey or pinkish-grey, thin-banded platy limestone cut by numerous small veins which run in a direction almost perpendicular to the lamination.

The microscope shows that the rock has been crushed and drawn out to such an extent that the original structure has vanished, and a fine calcareous powder has been produced arranged in slightly undulating, flattened, lenticular folia parallel to the direction of movement. The main foliation is crossed by an oblique minor banding, which is wavy and resembles the *Ausweichungsclivage* of many shales. There are *Augen* of uncrushed limestone, but many veins of granular calcite cut through the sheared mass, mostly perpendicular to the lamination, but sometimes parallel to it. They occasionally show slight traces of deformation, but as a whole are undoubtedly later than the shearing.

The finest exhibition of an overthrust, however, is to be found in the east side of Caswell Bay. The structure can be best determined by following the outcrop of a thick bed of light-coloured oolite. That rock crops out at the engine-house, and rises to the top of the east cliff close by. Beneath it we see in the foot of the cliff dark and thin-bedded limestones, including a thinner band of oolite, for about 130 yards, all dipping north,

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Mr. Strahan. when we reach the overthrust. The fracture-plane hades to the north, and a slight burring of the broken edges of the beds above it proves that they have been pushed southwards up it. Beneath it we find the thick white oolite again, dipping south. Then follows a syncline, in which the oolite temporarily passes

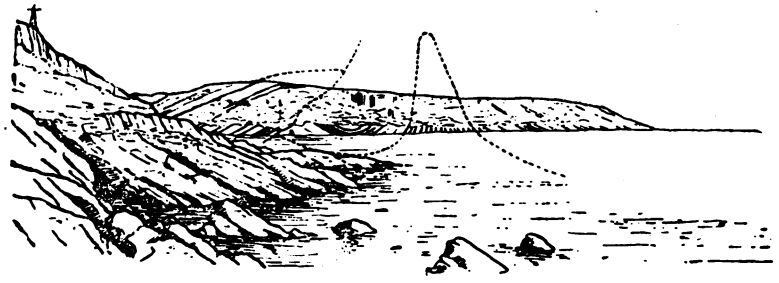

Fig. 2. *Overthrust in Caswell Bay.* (*From a photograph.*)
By A. STRAHAN.
(The dotted line indicates the base of the thick oolite referred to.)

beneath sea-level, and an extremely sharp anticline in which it temporarily passes above the top of the cliff. Here we reach beds with a uniform dip to the south. The structure, therefore, may be described as an anticline, with subsidiary folding, and with fracture and overthrusting. Perhaps because it is on the north side of an anticline, the thrust-plane slants northwards, and the beds have mounted from that side. The extent of the movement has probably amounted to 200 feet or more.

The relative age of this east and west system with the E.N.E. and W.S.W. system previously described still remains uncertain. That the east and west folds and fractures of the south are pre-Triassic is easily proved, but that the other system, which includes the Vale of Neath, Cribarth, Cennen, Gwendraeth Valley and other disturbances is of much later date, has been inferred partly from the fact that they directly determined the river-system, and partly from their relation to the N.N.W. system of normal faults. It was found that though the faults cut through all undoubtedly pre-Triassic structures, as for example, at Mitchin Hole, they generally failed to traverse the W.S.W. belts of disturbance, or in some cases appeared to be deflected by them. So far as the past year's work is concerned, not much further light is thrown on the subject. The Llanelly syncline is certainly cut through repeatedly, and would for other reasons have been assigned to the pre-Triassic set. But the Llannon disturbance, which ranges south-west, is believed by Mr. Dixon to be crossed similarly, while it is thought that some faults traverse the Cross Hands and Ammanford belt of disturbances. It should be noted however that the detailed structure of that region is not and never will be known, and that one of the principal N.N.W. faults which forms our best available explanation of what is visible on the surface, follows an unusually sinuous course, such as might have been caused by subsequent shifting.

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Further light may be thrown on the relative ages of the two systems by an investigation of the anthracitisation of the coals now in progress (p. 189). There is reason to think that a connection between the W.S.W. system and the anthracitisation may be traced, whereas the N.N.W. faulting appears to have been subsequent to the anthracitisation. Mr. Strahan.

## PLEISTOCENE.

### *Raised Beach.*

Two possible representatives of the Raised Beach have been found on the Carmarthen coast west of Gower. One occurs in the cliff east of Llanstephan Castle. Under 20 feet of Boulder Clay there lies a fine deep-red stratified loam with fine gravel composed chiefly of Old Red Sandstone detritus. The deposit is several feet thick and is but slightly above the present storm-beach. No shells occurred in it, and though it possibly represents the Raised Beach, it is at least as likely to be a stratified band in the Glacial Drift, like the gravel in Rhossili Bay described in the "Summary of Progress" for 1901, pp. 52, 53. The second example occurs immediately west of Ragwen Point at the western end of a small cliff of Boulder Clay. Concreted sand with small pebbles, and with blown sand, appears from beneath the Drift, just above high-water mark. No shells were observed. Mr. Wilkinson.

### *Glacial.*

The glacial phenomena of the region surveyed during the past year are connected with two main ice-flows, the one of which travelled westwards down the Towy Valley, with a tendency to escape southwards wherever the form of the ground permitted, while the other spread southwards over the Coal Field to the coast near Llanelly and Pembrey, filling, probably to overflowing, the valleys of the Loughor, Gwili, Morlais, Lliedi and other rivers. Mr. Strahan.

In the Vale of Towy Mr. Thomas finds that the Boulder Clay on the Ordovician outcrops consists entirely of grits and shales derived from more northerly districts, while on the Old Red Sandstone two varieties occur, the one a blue clay full of large far-derived boulders, the other a bright-red till composed almost entirely of the local material. Much of the Boulder Clay becomes gravelly westwards. Mr. Thomas.

The tendency of the ice to escape southwards is illustrated near Llanarthney where the Silurian escarpment breaks down. A valley trending S.S.W., and connecting the Vale of Towy with that of the Gwendraeth-fach, contains much Glacial gravel, brought down apparently by a part of the Towy ice-flow. As much as 40 to 60 feet of Boulder Clay can be seen in parts of the Gwendraeth-fach. Striæ on the Millstone Grit at Garn and other places point S. 22° W.

Boulder Clay has been distributed freely along the lower part of the valleys of the Towy, the Tâf, and their tributaries. Many of the boulders have been derived from the Old Red Sandstone, Mr. Wilkinson.



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Mr. Wilkinson. but some coarse grits or conglomerates resemble the older beds which crop out to the north-east. The same direction of glaciation is suggested also by the large boulders, apparently of Millstone Grit, which abound north-east of Kidwelly. Much of the Boulder Clay is gravelly, but a distinct deposit, consisting of bedded sand and fine gravel occurs on the plateau north of Pendine.

Mr. Cantrill. Within the limits of the Coal Field a large sheet of Boulder Clay extending from Llandybie southwards contains Carboniferous Limestone, Old Red Sandstone, and older rocks, which have travelled apparently in a S.S.W. direction. Some gravelly mounds lie with their longer axes in the same direction.

Another large tract extends from Cross Hands south-eastwards. There the bulk of the material is of Coal Measure origin, but Old Red Sandstone and Silurian boulders also occur. Some thin disconnected patches in the Gwendraeth Valley west of Cross Hands include some boulders of Millstone Grit and Old Red Sandstone, the latter increasing northwards towards its source.

The conclusions as to the direction of transport are confirmed by some striæ near Foel Gastell which point S. 25° W.

Mr. Dixon. In his examination of the region lying around Llannon and Sylen Mr. Dixon finds that the bulk of the Drift is composed of local Coal Measure rocks, though Old Red Sandstone is always present, and concludes that the material has been derived from a northern source. On Mynydd Sylen at a height of 850 feet above the sea there is a red drift composed chiefly of Old Red Sandstone, though in the Gwendraeth Valley, nearer to the source and 600 feet lower down, the Drift contains but little of that rock, the explanation possibly being that the Gwendraeth ice-flow was crossed obliquely by a higher flow moving more nearly southwards.

Striæ have been noted near Llanedy and between the Morlais and Gwili all pointing south, and below Pont Morlais pointing S 25° W.

Mr. Strahan. In the maritime region the Drift is mostly a gravelly Boulder Clay with an occasional mound of clean gravel. The boulders, among a vast majority of Coal Measure rocks, always include many of Old Red Sandstone, brought down presumably from the North Crop; but by what route they travelled it is difficult to determine, inasmuch as they are more abundant than in some of the valleys two or three miles to the north. Sand and fine laminated clay was found under Boulder Clay in the new reservoir in the Lliedi, and small lenticular bands occur elsewhere. Several striated surfaces have been noted, the direction of the striæ varying slightly from south when influenced by the form of the ground.

The depth of Drift in the low-lying and alluvial tracts is not so great as might have been anticipated. The Great Morfa Pit, of which the section is given on p. 178, reaches the rock at about 41 feet below Ordnance Datum, passing through two peat-beds.

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A trial-sinking at Mach-ynys showed nearly twice this thick- Mr. Strahan.
ness of superficial deposits:—

*Mach-ynys Pit and Boring.*

| | ft. | in. |
|---|---|---|
| Earth | 4 | 0 |
| Glacial Deposits:— | | |
| Gravel | 15 | 0 |
| Blue clay and boulders | 7 | 6 |
| Sand and gravel | 11 | 0 |
| Quicksand | 13 | 0 |
| Conglomerate | 1 | 3 |
| Gravel mixed with cliff-quar and blue stone | 7 | 6 |
| Bottom of Pit. Section continued in boring:— | | |
| Gravel mixed with oxide of iron | 12 | 0 |
| Soft muddy ground | 2 | 0 |
| Quicksand | 10 | 0 |
| Stiff blue clay | 1 | 6 |
| Hard gravel | 2 | 8 |
| Quicksand | 33 | 10 |
| Sandstone rock [? a boulder] | 3 | 2 |
| Quicksand | 3 | 0 |
| Rock | | |
| | 127 | 5* |

Another boring, half a mile to the E.N.E. and 500 yards north of the Great Morfa Shaft, reached the rock at 140 feet depth, while a third boring by the side of the Great Western Railway, 800 yards further north again, reached the rock at 92 feet depth. In the Llanelly new dock the rock was reached at a depth of a few feet only below Ordnance Datum. It would seem, therefore, that there is a buried valley running under Mach-ynys, and thence in an E.N.E. direction. The shafts and borings referred to all commenced at about 20 to 25 feet above Ordnance Datum, from which it will be seen that the rock lies as much as 115 feet below that level at the deepest point proved.

One more section remains to be noted. The trial-shaft at Elliott's Metal Company's Works at Burry Port, of which the section is given on p. 182, reached the rock at 58 feet, or about 35 feet below Ordnance Datum, but Stanley's Pit, of which no details have been obtained, is said to have traversed 120 feet of "superficial stuff," probably all Glacial Drift, before reaching the rock. The rock-surface must therefore be about 60 feet below Ordnance Datum, though it is close to the foot of a bare sandstone hill.

A section proved at Craig-lon may be mentioned here as showing the occasional difficulty of identifying Glacial deposits. A shaft and slant put down at the foot of the hill to the Gyscwm Vein passed through 51 feet of stiff blue clay with stones, underlain by 12 feet of loose sand crowded with sea-shells of recent species. The sand occurred at Ordnance Datum, and obviously formed the marginal deposit of the great marsh-tract of the Gwendraeth Estuary. Subsequently it was buried by

* In the Summary of Progress for 1901, p. 52, this depth was erroneously given as 120 yards.



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Mr. Strahan. what must have been a wash, or possibly a slip, from the steep hillside close by, which consists in the lower part of shale. The imitation of a boulder clay was close.

## ECONOMIC GEOLOGY.

The Cenrhos Rock which lies between the Gyscwm and Cenrhos Veins is one of the thickest and hardest Pennant sandstones in this part of the Coal Field. It has been quarried at Cwm Capel for use in the Barry Docks and other places, and is now worked at Gyscwm. A hard and massive Pennant is quarried also at the lower end of the lower Lliedi reservoir. Flags have been got for use in Llanelly from fine fissile sandstone near Brondini. The Llandilo Limestone is employed in districts near its outcrop. It is seldom dressed, being worked in flat slabs. The Carboniferous Limestone supplies much rough stone, while locally building material is got from the top of the Brownstones, from the green beds of the Senni Series and from the green beds at the base of the Old Red Sandstone.

Road-metal is got from hard quartz-grits which crop out in the Pennant at Fforest and Gwal-y-hwch. Llandilo Limestone is used locally on bye-roads, but Carboniferous Limestone for main roads. Bricks for building and engineering purposes have been made from the clays above the Gyscwm Vein and fire-bricks from the underclay of that vein. The Clay Vein was worked for the sake of its clay. The underclay of a small seam at Brondini, referred to on p. 189, and the shales above the seam have been used for the same purpose. The Carboniferous Limestone is quarried on a large scale at Honey-cors west of Laugharne, for burning and road-metal.

"Plastic clay" has been worked near Careg Gwenlas and Garn (see also p. 43) and the Millstone Grit, when it is sufficiently pure and not too hard, is worked for "silica sand." Much rotten grit occurs near Llyn-llech-owen, north of Gors-Lâs.

A lead-vein was worked some twenty-five or thirty years ago at Llandilo-rhwnws near Nant-garedig, in a rock of which the age is probably Tremadoc. The ore occurred as galena and appears to have been associated with blende and barytes. The vein seems to have ranged approximately north and south along a broken fold.

Lead-ore is still worked at Allt-Cystanog. A large mine, known as the "Vale of Towy," on the south side of the river near Carmarthen, yielded much galena. The vein, so far as can be judged from the waste-heaps, consisted of galena associated with vein-quartz, barytes and blende, with small quantities of copper-pyrites. The galena contained enough silver to pay for extraction. The vein probably ranges under the Towy to the neighbourhood of Abergwili.

Springs and shallow wells form the sources of water-supply for a large part of the area. Springs occur near the base of the Old Red Sandstone and at many other horizons in that formation, especially in the upper part where the dip is comparatively gentle. They issue also at the base of the Carboniferous Limestone.

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Carmarthen, till recently, obtained its water from two wells sunk in the alluvium of the Towy. The supply is now got from the Ordovician country to the north.

Llanelly is supplied from a reservoir in the Lliedi Valley in which the surface-water is stored. A second reservoir higher up the same valley has recently been completed. The water is supplied without filtration. For the villages the impounding of springs in the neighbourhood has usually sufficed.

## II.—Petrographical Work.

During the year 1902 the rooms assigned to this department have been vacated owing to structural alterations in the Museum. New and improved accommodation has been provided and all the collections of sliced rocks and rock sections have been removed to their new quarters. The rock specimens exhibited in the museum have also been transferred to the gallery which was formerly occupied by the collection of pottery. The large amount of extra work entailed by these changes has been overtaken by Dr. Flett and Mr. John Rhodes and has necessarily to some extent interfered with the ordinary duties of the department. Dr. J. S. Flett.

The material sent in for microscopic examination has been contributed by every district which is being mapped in England and by all the field officers in Scotland. It includes an immense variety of rock types, many of which are of considerable scientific interest, and it would be impossible in this Report to discuss the important questions which they raise. A few of the more salient points, however, may be briefly considered.

### The Green Beds of the Southern Highlands of Scotland.

The presence, among the altered sedimentary rocks of this region, of hornblende-schists, presumably of sedimentary origin, has been recorded in the "Summary of Progress" of previous years. They extend from Cowal to Aberdeenshire, and, as mapped out by the field officers, have, on the whole, a well-marked and continuous outcrop; but in the different districts they vary greatly in their characters, so that the green beds of Cowal and southern Argyllshire are in many ways unlike those of Perthshire and Aberdeenshire. Those of Cowal have been described in the memoir on that area, and are mostly chloritic and micaceous schists, which contain a variable amount of quartz, and sometimes epidote and albite. In them hornblende does not occur, or, at any rate, is very scarce, and this is also the case in the Loch Lomond area to the east of Cowal, where the green beds are mostly chloritic and epidotic grits, though, in the north part of that sheet (38 Scot.) hornblende begins to appear. But, as the outcrop is traced in a north-easterly direction through Perthshire, hornblende rapidly increases in abundance, and becomes, in fact, the characteristic mineral in this group of

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Dr. Flett

rocks. In the neighbourhood of Aberfeldy Mr. Cunningham Craig* has mapped out a set of green beds, which, while undoubtedly of sedimentary origin, exhibit many of the features which are found in igneous hornblende-schists. Yet the clastic nature of the rocks can, in most cases, be definitely established, as, in the exposures a little south of Aberfeldy, pebbly quartz grains can be traced in lines along the face of the rock, which can only be regarded as clastic fragments disposed along the bedding planes. On the north side of the Tay similar rocks outcrop, but there the pebbly character is much less pronounced, and they are represented by fine, well-foliated hornblende-schists which simulate, with extraordinary perfection, the finer grained types of intrusive hornblende-schist of the region in question.

A microscopic study of sections of these green beds proves that they are hornblende-schists, mostly fine-grained, with small, water-clear crystals of felspar, and occasionally dark brown flakes of biotite. Many of them contain idiomorphic garnets of a wine-red colour. The various stages in the disappearance of the quartz grains are most interesting, and are perfectly exemplified in the slices prepared for Mr. Cunningham Craig. At first the pebbles begin to break down at their margins, and gradually the process of granulitisation spreads inwards through the grains till they become a fine mosaic of quartz, which is permeated by needles of green hornblende, which have spread inwards from the surrounding matrix. Finally the quartz grains disappear, and are indistinguishably blended with the mass of the rock, in which they form small, irregularly lenticular patches parallel to the foliation, or are altogether lost.

### THE SCHIEHALLION BOULDER BED.

Among the schists of the southern Highlands, as has been mentioned in more than one of the Summaries of Progress, there are certain sheared conglomerates, or "conglomerate gneisses," in which occur pebbles of rock, still older than the surrounding schists. These have been involved in the earth movements which have affected the whole district, and they, as well as the matrix in which they lie, have undergone shearing, attended by recrystallisation. But in the Schiehallion district of Perthshire a boulder bed has been mapped by Mr. J. S. Grant Wilson, which is still not so greatly modified as to render it difficult to recognise the original character of its ingredients. A great variety of pebbles is to be found in this bed, most of them schists and gneisses, which prove the existence of a metamorphic terrane in this region before the "Dalradian" schists were deposited as sub-aqueous sediments.

Among these are others which are of interest to the petrologist, from their rarity as rock types. Very fine examples of scapolite-amphibolites (dark-coloured rocks consisting of scapolite

* Summary of Progress for 1901, p. 167.

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and hornblende), and scapolite-hornblende gneisses (which contain scapolite, felspar, hornblende, and quartz) are to be met with, and there are also granites which are so rich in microcline and other alkali felspars, that they may be placed in the group of "alkali granites." The matrix is a sandy and argillaceous material, which, with advancing metamorphism, becomes a fine-grained biotite gneiss or granulite, and, where the changes have been least profound, the original characters of the pebbles are still perfect, but, as shearing progresses, cataclastic structures make their appearance, and become more and more conspicuous. Dr Flett.

### THE MOINE SCHISTS OF SUTHERLANDSHIRE.

A group of rocks from this series in the vicinity of Aultnacallagach has been sent in by Mr. B. N. Peach in order to elucidate the changes undergone by both sediments and igneous rocks in this region. From an examination of these it is clear that, above the Moine thrust plane, there is in this place a band of rocks which have undergone intense shearing, though at the same time the original clastic structures of the sediments are still traceable in some of the specimens, and the dykes of porphyrite have not lost their typically igneous characters. Every stage of granulitisation down to complete mylonisation can be exemplified, and, from a comparative study of the specimens the original nature of the rocks can be perfectly established. Before the movements along the Moine thrust began, they were in all probability little modified types of sedimentary and crystalline igneous rocks, and, if the dykes belong to the post-Cambrian series of intrusions, (as there seems much reason to believe) it is clear that some part at least of the Moine schists of Sutherlandshire were still in the condition of ordinary sedimentary rocks at the close of Cambrian time.

### THE RECENT ERUPTIONS IN THE WEST INDIES.

The disastrous calamity which overtook the British Colony of St. Vincent in May 1902, though less terrible in its consequences than the destruction of St. Pierre, awakened wide-spread sympathy in the mother country, and the remarkable circumstances with which it was attended, led the Royal Society of London, on the suggestion of the Colonial Office, to send out a scientific commission to report on the facts. Dr. Flett was chosen as one of the members of this commission and, with the permission of the Board of Education, he proceeded to the scene of the eruptions along with Dr. Tempest Anderson. The preliminary report of this commission was published shortly after their return to Great Britain and contains an outline of the history of the catastrophe and of the geological observations which they made during their visit to the West Indies. A fuller report has since been published by the Royal Society.*

*Phil. Trans.* Series A, vol. cc., pp. 353-553, 1903.

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## III. Chemical Work.

Dr. W. Pollard.

In the "Summary of Progress" of 1899 (p. 185) Phosphatic nodules from the Torridon Sandstone were mentioned. One of these has since been analysed (8760) also a Phosphatic nodule from the Carboniferous Limestone of Westmorland, the result of these analyses are appended.

Mr. Teall gave the following description of (8760):

"Cailleach Head, Loch Broom.

"Dark compact shale containing two black lenticles (1 × 1 × ¼ in.) The shale is composed of minute grains of quartz and felspar (.05 m.m. or less) and two micas. Epidote grains are fairly abundant. The transverse section shows that the rock is distinctly laminated, some layers being composed almost entirely of quartz, felspar, and epidote; others contain the two micas in abundance associated.

"The lenticles consist of the finer portions of the sedimentary material, especially micas, cemented with brown amorphous phosphate. They contain also minute black spherical bodies, brown fibres, or black or brown shreds, some of which show a distinct cellular structure. The cells measure about .01 m.m. in diameter, and are clustered in groups. The natural form is spherical, but this is sometimes interfered with by mutual pressure so that the cells have polygonal outlines. In such cases the fragments resemble portions of the parenchymatous tissue of plants, except as regards size. The black spheres show no structure where they are wholly immersed in the phosphatic matter; but when, as happens at least in one case, about half has been removed in the process of making the section, they are then seen to have been hollow and apparently perforated. The spheres vary from about .005 to .035 m.m. in diameter.

"The brown fibres are about .004 m.m. in breadth and of lengths varying from a few hundredths to tenths of a millimetre. They may be straight, curved, or even looped.

"That these various bodies represent organisms is highly probable; but the nature of the organisms is doubtful.

"The planes of lamination can be followed into the nodules, but they are more widely separated in the nodule than in the matrix, and the external planes of lamination curve inwards at the edges of the nodules. These facts appear to indicate that the concentration of phosphatic matter took place during, or immediately after, the deposition of the sediment.

A similar concentration of phosphatic matter has taken place sedimentary rocks of many different geological periods, but in most cases the loose deposit in which the action occurred has been winnowed away by a process of contemporaneous erosion; so that the nodules are not as a rule embedded in their original matrix, as they are in this case.

The nodule from the Carboniferous Limestone, Westmorland, was collected by Mr. J. Rhodes, and described in a paper entitled "Notes on the occurrence of Phosphatic Nodules and Phosphate-Bearing Rock in the Upper Carboniferous Limestone (Yoredale) Series of the West Riding of Yorkshire and Westmorland Border." *

ANALYSIS OF PHOSPHATIC NODULES.

I. Slice No. 8760. Cailleach Head, Loch Broom, Ross-shire.
"Uppermost Beds of Torridon." 101.
12. N.E.

II. Slice No. E. 3714. Farcote Gill, Wild Boar Fell, Westmorland.
"3 in. Nodular Bed on Little Limestone Chert." 1″ 40, 6″ 36.

*Rep. Brit. Assoc. for 1901, p. 655.

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Dr. Pollard.

| | I. | | II. |
|---|---|---|---|
| Residue. Insol. Nitric Acid. | | 37·08 | 18·74 |
| | | Part sol. in Nitric Acid. | |
| $SiO_2$ - - | 29·99 | 2·26 | 14·68 |
| $TiO_2$ - - | ·40 | — | Trace? |
| $Al_2O_3$ - - | 8·58 | 2·46 | 6·36 |
| FeO - - | 4·22 | 4·22 | 1·03 |
| MnO - - | ·35 | — | ·36 |
| (CoNi)O - - | ·12 | — | ·15 |
| CaO - - | 26·93 | 25·63 | 40·02 |
| MgO - - | 1·50 | 1·50 | ·55 |
| $K_2O$ - - | 1·54 | ·46 | 1·25 |
| $Na_2O$ - - | ·30 | ·10 | ·55 |
| $Li_2O$ - - | Trace | — | — |
| $P_2O_5$ - - | 20·29 | 20·29 | 28·98 |
| F - - - | 1·15 | — | 1·55 |
| Organic Matter | 1·48 | — | 1·46 |
| $CO_2$ - - - | 1·96 | — | } 4·08 |
| $H_2O$ at 105° | ·48 | — | |
| $H_2O$ above 105° | 1·55 | — | |
| Total. | 100·84 | | 101·02 |
| Less O for F. | ·48 | | ·65 |
| | 100·36 | | 100·37 |

## NEPHELINE.

Nepheline separated from Nepheline-Aegirine-Syenite-Pegmatite. (9322.) A boulder from Coulmore, Ross-shire. 1″ 101.

Separated by Bromoform diluted with Xylene.
Sp. gr. between 2·60–2·68.

| | % | Molecular ratios | |
|---|---|---|---|
| $SiO_2$ - - - | 44·87 | - - | ·7429 | |
| $Al_2O3$ - - | 32·00 | - - | ·3131 | |
| $Fe_2O_3$ - - | 1·53 | - - | ·0095 | |
| CaO - - - | ·47 | - - | ·0084 | |
| $K_2O$ - - - | 6·72 | - - | ·0712 | ·2967 |
| $Na_2O$ - - | 14·00 | - - | ·2255 | |
| $H_2O$ 105° - - | ·11 | - - | — | |
| $H_2O$ above 105° | ·87 | - - | ·048 | |
| Total | 100·57 | | | |

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Dr. Pollard.

Theoretical composition for $3Na_2O$, $K_2O$, $4Al_2O_3$, $9SiO_2$.
($R_8Al_8Si_9O_{34}$ where $R = K:Na = 1:3$.)

| | |
|---|---|
| $SiO_2$ | 44·0 |
| $Al_2O_3$ | 33·2 |
| $K_2O$ | 7·7 |
| $Na_2O$ | 15.1 |
| Total | 100·0 (From Dana.) |

An analysis of the felspathic constituent of this rock was made last year and will be found in *Summary of Progress*, 1901, p. 86.

White Mineral (alteration after Nepheline ?) from a vein east of Ault a Mhullin, east of Ault na Calla Gach.

| | | Mol. Rat. | |
|---|---|---|---|
| $SiO_2$ | 43·35 | ·7177 | |
| $Al_2O_3$ | 31·93 | ·3124 | |
| *$Fe_2O_3$ | ·78 | ·0049 | |
| CaO | 1·53 | ·0273 | |
| MgO | ·28 | ·0069 | |
| $K_2O$ | 6·16 | ·0653 | ·1996 |
| $Na_2O$ | 8·03 | ·1293 | |
| $Li_2O$ | ·15 | ·0050 | |
| $CO_2$ | ·57 | ·0130 | |
| $SO_3$ | 1·67 | ·0209 | |
| $H_2O$ 105 | ·38 | ·0211 | |
| $H_2O$ above | 5·47 | ·3036 | |
| Total | 100·30 | | |

MnO trace. Cl, F, not found.

CLAY.

Analysis of Clay from Waterloo Brickfield, Reading. (Messrs. Poulton & Sons).

Mottled Clay of Reading Beds. Collected by H. W. Monckton, October 8th, 1902.

| | |
|---|---|
| $SiO_2$ | 53·43 |
| $TiO_2$ | ·84 |
| $Al_2O_3$ | 18·77 |
| $Fe_2O_3$ | 9·42 |
| CaO | ·51 |
| MgO | 1·40 |
| $K_2O$ | 3·39 |
| $Na_2O$ | ·54 |
| $H_2O$ at 103° | 5·55 |
| $H_2O$ above 103° | 6·59 |
| Total | 100·44 |

Trace of $Li_2O$, MnO.

FeO cannot be estimated with any certainty owing to the presence of a little organic matter ; all iron calculated as $Fe_2O_3$.

| | Per cent. |
|---|---|
| Sand | 21·9 |
| Silica (combined) | 31·6 |
| | 53·5 |

* State of oxidation not determined.

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## MOTTLED LIMESTONE.

Dr. Pollard.

The following Analysis of a specimen taken from a quarry on the road between Oxwich and Oxwich Castle, Gower, Glam. was made to prove that the cause of the "mottled" appearance of one of the beds of the Carboniferous Limestone in Gower was due to dolomitisation. In thin section the light part (dolomite), is seen to be crystalline and devoid of organic structure, whilst the darker portion (mostly limestone) shows organic structure distinctly. Here and there in the dark part rhombs of dolomite can be observed. The dark and light portions were separated by picking out (it was impossible to get a clean separation), and analysed with the following results :—

| | Light. | Dark. |
|---|---|---|
| Part insoluble hot dil. Hydrochloric, dried at 105° | 5·85 | 2.42 |
| Water at 105° | ·21 | .06 |
| Oxide of iron, etc. | ·63 | .25 |
| Lime | 34·17 | 50.98 |
| Magnesia | 15·29 | 3 21 |
| Carbonic acid | 43·60 | 43·62 |
| TOTAL | 99·75 | 100·54 |

Ratio of lime to magnesia to carbonic acid :—

| | | | | | | |
|---|---|---|---|---|---|---|
| Light | 1·61 | - | 1 | - | - | 2·62 |
| Dark | 11·47 | - | 1 | - | - | 12·46 |

The above figures clearly show that the light part is dolomite with some limestone, whilst the dark is almost entirely limestone.

## LAUMONTITE.

Mineral occuring with granite from the Baveno Granite Quarries. (Presented by Mr. Hamilton Gunn.)

| | | Mol. Rat. |
|---|---|---|
| Silica. | 51·35 | ·8501 |
| Alumina. | 22.14 | ·2166 |
| Ferric Oxide. | ·67 | ·0042 |
| Lime. | 12·35 | ·2205 |
| Water. | 13·65 | ·7575 |
| Total | 100·16 | |

(At 105° 1·78% of the water is driven off, 1·25% between 105° and 200°.)

This gives the ratio,

Silica to Alumina, to Lime, to Water :—

3·92 1 1·01 3.49

Laumontite is :—

4 1 1 4

There can be no doubt that this is that mineral, with some of the water lost.

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## BARYTO-CELESTITE.

Dr. Pollard.

### Partial Analysis of Baryto-celestite from Chipping Sodbury railway-cutting.

Specimen sent by Mr. W. H. Wickes, Bristol.

| | |
|---|---|
| BaO | 24·48 |
| SrO | 31·89 |
| CaO | 1·22 |
| $SO_3$ | 39·03 |
| *$Fe_2O_3$ | 1·26 |
| Loss on Ignition | 1·81 |
| Total | 99·69 |

## VOLCANIC ASH.

Analysis of pumice separated from Volcanic Ash which fell in Barbados on May 7–8th, 1902. Sp. Gr. below 2·44.

| | |
|---|---|
| $SiO_2$ | 59·97 |
| $TiO_2$ | ·72 |
| $Al_2O_3$ | 18·13 |
| $Fe_2O_3$ | 2·28 |
| FeO | 3·95 |
| MnO | Trace |
| CaO | 6·62 |
| MgO | 2·44 |
| $K_2O$ | 1·09 |
| $Na_2O$ | 4·11 |
| $H_2O$ | ·48 |
| $P_2O_5$ | ·21 |
| (CoNi)O | Trace |
| Total | 100·00 |

## CHROMIUM AND VANADIUM IN BASIC ROCKS.

A short time ago Sir Norman Lockyer examined spectroscopically a few basic rocks which had been analysed in this laboratory and noted the presence of vanadium and chromium in the majority. The fact that these constituents often occur in rocks has been known for some time, but it seemed worth while determining the quantities in a few specimens from Great Britain. Recently a large number of rocks from the United States have been thus examined in the laboratory of the United States Geological Survey and the analytical methods used described.† These methods have been followed in the examination of a few British rocks, and the values for $Cr_2O_3$ and $V_2O_3$ are given below—

| | %$Cr_2O_3$ | %$V_2O_3$ |
|---|---|---|
| 8062 | ·01 | ·06 |
| 8057 | (·004) | ·03 |
| 8043 | ·03 | ·03 |
| 8194 | ·02 | ·02 |
| 8185 | ·04 | ·04 |

* State of oxidation not determined.

† W. F. Hillebrand. Bull. U.S. Geol. Survey, No. 167, p. 49; No. 176, p. 82.

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In [8057] Chromium was found spectroscopically first, otherwise it would hardly have been suspected, as the colouring was very weak. Naturally this figure must be regarded only as a rough approximation. Dr. Pollard.

Names and Localities of above rocks:—

8062. Loch a'Bhastelr, Skye. Dolerite. (Analysis "Summary," 1901, p. 87.)
8057. Brochbeinn, Skye. Olivine Basalt. (Analysis "Summary," 1899 p. 172.)
8043. Sligachan river, west bank, just below junction with Allt Coire Riabhaich. Olivine Gabbro. (Analysis "Summary," 1899, p. 172.)
8194. Coire a'Mhadaidh, Skye. Gabbro. (Analysis "Summary," 1899, p. 172.)
8185. Alltt Feionn Fharadid, Drynoch, Skye. Olivine Basalt (lava) (Analysis "Summary," 1899, p. 172.)

## IV. Palæontological Work.

Upwards of 4000 specimens of fossils have been received and registered in the books of the department and the greater part determined specifically. Between three and four hundred of these fossils have been mounted and added to the collection exhibited in the Museum. Mr. E. T. Newton.

The nomenclature of the Rhætic and Jurassic Mollusca in the collection is being revised by Mr. H. A. Allen, and this work has occupied the greater part of his time during the year. He has now completed the revision of the Lamellibranchiata and Gasteropoda from the Rhætic, Lower, Middle and Upper Lias, and also the Gasteropoda of the Inferior Oolite It has been found convenient while prosecuting this task to make a list of the type and figured specimens. This important and useful piece of work has been carried out by Mr. Allen, and a catalogue of the type and figured Gasteropoda from the Rhætic to the Inferior Oolite inclusive is printed as an appendix to this Summary (see page 217). A similar revision of the nomenclature of the Eocene and Oligocene Vertebrata has been carried out by Mr. Newton, but the catalogue of the types was published as an appendix to the Summary for the year 1900.

The specific determination of the series of fossils, chiefly Jurassic, collected by Mr. C. B. Wedd and Mr. D. Tait in 1901, in the islands of Skye and Scalpay, has occupied a large part of Dr. F. L. Kitchin's time. The species determined from both marine and estuarine beds will doubtless in the near future be of much value in the correlation of the strata, but call for no special notice at the present time. Much interest attaches to the discovery of Cretaceous beds in Scalpay as shown by the presence of *Pecten asper*, a preliminary note on which appeared on page 145 of last year's Summary.

The determination of certain species among fossils from Lower Palæozoic beds in South Wales collected by Mr. T. C. Cantrill and Mr. H. H. Thomas has been of value in settling definite horizons in that district. Mr. J. Pringle has been

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Mr. E. T. Newton.

occupied in collecting Carboniferous fossils in South Wales and was for part of the time accompanied by Mr. J. Rhodes. The chief object of this collecting was to obtain a large series of Coal Plants from definite horizons in order to assist Mr. R. Kidston in the Palæobotanical work on the district, which he has been good enough to undertake for the Survey. Besides these fossil plants which are now being worked out by Mr. Kidston, and a series of mollusca, Mr. Pringle was fortunate enough to obtain some examples of those rare fossils Limuloids and Arachnids, *Prestwichia* and *Eophrynus*, as well as a Myriapod and some insect wings. The invertebrata of this collection have been determined by Dr. Kitchin.

On two occasions Mr. Newton visited Derbyshire to examine the cave which had been discovered at Longcliff, and for the purpose of studying the mammalian remains that had been unearthed. The cave has since been explored by Mr. Arnold Bemrose, under the auspices of the Derby Antiquarian Society, and Mr. Newton has been able to arrange that a series of the remains be reserved for this Museum.

We are under obligation to several gentlemen who have been kind enough to lend specimens for Survey purposes. Mr. J. de W. Hinch sent a series of glacial shells from County Dublin at Mr. Lamplugh's request. Mr. W. Whitaker placed at our disposal a number of fragmentary shells, representing fifteen species from a well boring at Lowestoft, which showed the existence of Norwich Crag at a depth between 138 and 181 feet. At Mr. T. I. Pocock's desire Messrs W. Hunter and R. E. Middleton, engineers for the Staines Reservoirs, were good enough to lend us certain specimens obtained from the Thames Alluvium, near Staines, among which Mr. Newton recognised the Antlers and other parts of an Elk (*Alces machlis*). Although this species has been several times met with in the north of England and Scotland, it has only once before been found so far south as the Thames and that was at Walthamstow, in Essex; Sir R. Owen, in 1869, having determined some limb bones from that locality. In the present instance the skull with both antlers, as well as the lower jaw with perfect teeth, and a tibia, supply much more satisfactory evidence that the Elk extended so far south as the Thames. A full account of this specimen has been published by the Geological Society, and while these pages have been passing through the press, the Joint Committee of the Staines Reservoirs, at the suggestion of the engineers, have courteously presented the remains to this Institution, where they may be seen exhibited in the Museum.* (See also p. 207.)

Mr. Ll. Treacher has kindly lent us a number of Eocene fossils collected by himself at Wokingham and Sonning, which has enabled us to add to Mr. Blake's Memoir on the Geology of Reading a good list from the top beds of the London Clay, at the former locality, and to verify many of the species recorded by Prestwich from Sonning. Mr. George Morris has lent us some

* *Quart. Journ. Geol. Soc.*, vol. lix p. 80.

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Lower Cretaceous fossils from the Snettisham Clay of Heacham; and Mr. Neilson a few Rhætic specimens from Arran. Mr. E. T. Newton.

Mr. Howard Fox and Mr. W. Barratt have presented to the Survey a series of interesting but obscure fossils found in the Devonian Shales near Newquay, from which neighbourhood Mr. Clement Reid has also made a collection.

The necessity for an easy mode of reference to the localities from which fossils have been collected has led to the preparation of a card catalogue..

The correction in proof of the palæontological portions of various Memoirs passing through the press has demanded a large amount of time, and this has been especially the case with the Memoir on the "Cretaceous Rocks of Britain" by Mr. A. J. Jukes-Browne, since it has been necessary to verify several of the lists of fossils as well as to revise much of the nomenclature.

Our thanks are due to several donors of fossils, and a detailed account of their presentations will be found among the list of donations to the Museum published in the Annual Report of the Survey.

The collection of fossils continues to be much used by workers in Palæontology and part of the officers' time has been occupied in assisting, as far as might be possible, such workers in their studies, and also in answering the numerous enquiries relative to fossils.

The following is a list of the specimens in the Museum which have been figured during the year:—

In the PALÆONTOGRAPHICAL SOCIETY, Vol. lvi, 1902.

By Miss E. M. Wood and Miss G. L. Ellis:—

Dichograptus octobrachiatus (*Hall*).
Dichograptus octobrachiatus (*Hall*) var. Sedgwicki, *Salter*.
Bryograptus Kjerulfi, Lapworth

By Mr. Hy. Woods.

Pecten orbicularis, *Sow.* var. haldonensis, *Woods*.
——— curvatus, *Gein.*
——— subacutus, *Lam.*
——— Robinaldinus, *d'Orb.* (2 specimens.)
——— arlesiensis, *Woods*
——— pulchellus, *Nilss.*

In the QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY

Vol. lviii, 1902. By Mr. C. A. Matley.

Obolella (?) Salteri, *Holl* (2 specimens.)
Linnarssonia Belti, *Dav.*

By Miss J. Donald.

Murchisonia (?) dudleyensis, *Donald*
Cyrtostropha bicincta, *M'Coy*
——— obscura, *Portl.*
Lophospira (?) angulocincta, *Salt.*

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## V. MUSEUM OF PRACTICAL GEOLOGY.

### The Geological Museum.

Mr. J. A. Howe.

During the year the Museum has benefitted by an important donation, presented by Col. Waldo-Sibthorpe. This is a collection of nearly 400 specimens, mostly of polished chalcedonies and agates but comprising also a number of precious stones, cut and in the rough state. Especially noteworthy is a very fine diamond in the matrix.

A small collection of about 60 specimens illustrating the ores of Greece has been presented by the Foreign Office and is now on exhibition.

Messrs E. Davis and Co. have presented some very large plates of Mica from India.

Among the specimens acquired by purchase may be mentioned a series of Calcite, Fluorite, Barytes, Quartz, Zinc Blende and other minerals from the North of England.

### The Library.

A number of useful additions, the majority by purchase, have been made during the year.

The work of constructing a card catalogue of the contents has been commenced and is now rapidly nearing completion.

All the Geological Survey Maps accessible to the public have been handed over to the Library; it is hoped that this arrangement will make for the increased convenience of enquirers.

## II. SCOTLAND.

Dr. J. Horne.

The ground surveyed in the Highlands was arranged in four districts, as follows:—

1. Knapdale and Lorne, Argyllshire, northwards to Loch Shiel, under Dr. Peach, F.R.S.
2. Central and Eastern Ross with parts of Inverness-shire and Sutherland, under Mr. Gunn.
3. Forest of Gaick, Atholl Forest and Glen Truim, under Dr. Horne, F.R.S.
4. The Islands of Rum and Eigg, under Dr. Peach, F.R.S.

The revision of the Carboniferous areas in Scotland having been sanctioned by the Board, the ground to be revised was arranged in two districts.

A. Midlothian with parts of West and East Lothian and Peeblesshire, under Dr. Peach, F.R.S.

B. District from Prestonpans to Cockburnspath and southwards to the Lammermuirs, under Mr. Clough, M.A.

In the district extending from Knapdale and Lorne in Argyllshire north to Loch Shiel, field-work was carried on in two subareas (1) in Sheet 36 which was completed; (2) in Sheet 53 on the north side of Loch Linnhe. The small unsurveyed area in Sheet 45 was finished and geological boundary lines were

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traced for short distances into Sheets 28, 44, 52 and 62. The Memoirs on Sheets 37 and 45 (Argyllshire) are nearly completed, and an effort will be made to publish them simultaneously with these sheets. Dr. J. Horne.

In the district of Central and Eastern Ross, with parts of Inverness-shire and Sutherland, the areas surveyed lay chiefly in Sheets 93 and 83. Upwards of 25 square miles still remain to be completed in Sheet 83. Small tracts were also mapped in Sheets 102 and 73.

In the Eastern Highlands the remaining unsurveyed portions of Sheet 64, extending from the Forest of Atholl north by Gaick Forest and Glen Truim to Newtonmore were mapped. Boundary lines were also traced for a short distance into Sheets 63 and 74. The Memoir descriptive of Lower Strathspey (Sheet 85) was published last year and the Memoir on the country round Pitlochry (Sheet 55) is in preparation.

In the district of Rum and Eigg, considerable progress has been made with the mapping of these islands.

The Memoir on the Tertiary Igneous Rocks of Skye has been completed and is ready for publication; and the Memoir on North Arran, South Bute, the Cumbraes, parts of the coasts of Ayrshire and Kintyre is in paged proof.

The revision of the Carboniferous areas of the Lothians was begun in October and continued till December; considerable progress having been made with the work during that period. The coast section from Cockburnspath to Dunbar, which shows an excellent section of Lower Carboniferous rocks, was re-examined with the view of comparing the latter with their equivalents along the Scottish border and in Midlothian. The limestones underlying the Edge coals have been traced along the east and south-east side of Midlothian basin. Additional information has been obtained regarding the oil-shale fields west of Edinburgh, and the volcanic rocks of the Pentland Hills, Arthur's Seat and the Calton Hills were re-examined.

The Memoir on the Geology of East Fife, embracing the great development of Carboniferous Rocks extending from St. Andrews to Leven and Buckhaven, was published last year.

## I.—FIELD WORK.

### 1. Argyllshire—Knapdale, Lorne, and Northwards to Loch Sheil.

Dr. B. N. Peach, F.R.S., District Geologist.
Mr. J. S. Grant Wilson.
Mr. H. Kynaston, B.A.
Dr. C. B. Crampton.
Mr. H. B. Muff, B.A.
Mr. E. B. Bailey, B.A.
} Geologists.

The geological formations entering into the structure of the district are the Highland Metamorphic rocks of sedimentary and igneous origin, Lower Old Red Sandstone and associated volcanic and intrusive rocks, Tertiary intrusive rocks, Glacial deposits, Raised beaches, Peat and Alluvium. Dr. Peach.

(*a*) *Crinan north to Kilmelfort with the adjacent islands (sheet 36).*



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Dr. Peach.

*Physical Features.*—The area surveyed in Sheet 36 is part of the low tableland, now forming the West of Argyllshire, which has been carved into hill and valley by subsequent streams, at a time when the land stood at a higher level. It has been depressed at a later geological period, so that sea lochs and sounds now fill the lower parts of the valleys, while the promontories and numerous islands fringing the coast represent the ancient dividing ridges and hill tops. The whole region bears evidence of having been profoundly modified by glaciation, and the raised beaches and rock notches show that the land has undergone slight elevation at different times since the glacial period.

The topography of the region varies in accordance with the underlying rocks and their arrangement, so that each area has its own characteristic features.

Messrs. Peach, Crampton, Muff and Bailey.

The Crinan district embraces part of the region lying between the Crinan Canal and Loch Sween, which is an extension southwards of the low plateau described in last year's Summary of Progress (p. 126). In the present area the narrow rocky, trench-like valleys, containing many lochs, have offered great facilities to the engineers to construct dams for impounding the enormous volume of water required for the Crinan Canal. The capabilities of the area for this purpose, as well as for water supply and motor power, are by no means exhausted.

In the lower part of the promontory of Craignish, lying between Loch Melfort and Loch Craignish, the same parallel N.N.E. and S.S.W. ridges, due to folded sheets of epidiorite, are observable as in the Kilmartin area, but the ridges are mostly below the 500 feet level. In the upper part, lying between Loch Melfort and the Barbreck river, the ground suddenly rises into a flat plateau, part of which reaches a height of 900 feet. The highest elevation—Tom Soilleir (1,199 feet)—from which the streams radiate, is evidently due to the masses of granite by which the area is invaded. The whole country is well watered and divided into moderate-sized farms where sheep and cattle are reared. That the soil is suitable for the growth of trees is clearly shown by the plantations near Craignish Castle, Lunga, Barbreck, and other localities.

With the exception of a narrow selvage of schistose rocks near the shore, the whole of the area north of Loch Melfort is occupied by andesitic lavas of the Lorne Volcanic plateau, which give rise to the terraced escarpments and flat tops so characteristic of that formation. Here the tableland attains an average height of about 500 feet, though a large part reaches a still greater elevation, the culminating point being Cruach Nam Fearna, which is over 1,000 feet. This area is divided into large farms for rearing cattle and sheep. The country is well watered and admirably suited for the growth of timber.

The island of Scarba is a continuation north-eastwards of the ridge of Jura, being separated from it only by the stormy Gulf of Corryvreckan. It forms a low conical hill of almost bare quartzite rising to 1,470 feet, on the east side of which there is

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a strip of black schist and limestone, affording moderately good pasture, and a coppice of natural brushwood. The island is entirely in deer forest, and the population consists of the game-keepers and their families. Some plantations of fir and larch show that these trees thrive in sheltered localities. Lunga is a continuation northwards of the ridge of Scarba, but at a lower elevation. It forms one sheep farm, with one house tenanted by the shepherd. All the other islands, with the exception of Belnahua, which has a considerable population due to the presence of a large slate quarry, and Fladda, which has a light-house, are mere holms, rocks, and skerries grazed by sheep and cattle during part of the year, but have no permanent inhabitants. Messrs. Peach, Kynaston, Muff and Bailey.

HIGHLAND METAMORPHIC ROCKS.

*District embracing Knapdale, Lorne, Scarba, Lunga, etc.*— The schistose rocks of sedimentary origin entering into the geological structure of this district are shown in the following table in descending order under local names:— Dr. Peach.

IV. Scarba, Jura and Islay quartzite group.
III. Degnish and Shuna Limestone.
II. Easdale Slates and Limestone.
I. Craignish Phyllites.

The schistose igneous rocks consist entirely of epidiorites and their modifications.

## *I.—Craignish Phyllites.*

As the name implies, these rocks are most typically developed in the promontory of Craignish and extend north-eastwards into the high ground lying between the Barbreck River and Loch Melfort, where they are much invaded and altered by granite. On the north shore of Loch Melfort they form a narrow strip of land between that Loch and the Old Red Volcanic platform, and they likewise make up the greater part of the Island of Shuna. Messrs. Peach, Kynaston, Muff and Bailey.

*Craignish.*—The sedimentary schists in Craignish consist of green and grey silky phyllites with calcareous sandy bands. A well marked strain-slip cleavage in the phyllites is inclined at about 60° to the E.S.E., but the dip decreases to about 40° on the west coast. The isoclinal folding is well brought out by the sandy and calcarous bands and by the epidiorite sills, which show that there is a general dip of all the rocks to the E.S.E. Usually the folds are so much thrown over to the W.N.W. that the dip of the bedding is less than that of the cleavage and on the western shore the beds are often nearly flat. The calcareous bands are represented by a whitish horny rock, showing an appreciable amount of sericite. This alteration does not appear to be due to any local "contact action," but was found to be present all over the district west of the Barbreck River. The harder calcareous and quartzose bands have suffered much compression, each bed being contorted into a series of short, Mr. Muff.



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Mr. Muff.

tightly packed folds, which considerably increase its true thickness. Sometimes each fold has been separated off from the adjoining ones by the shearing movements which have taken place, and a structure is produced resembling a row of pebbles embedded in the phyllites.

The sills of epidiorite intruded into the phyllites are thinner than those associated with the schists on the east side of Loch Craignish, but, as in the latter district, a coarse-grained massive kind may be distinguished from a finer-grained well-cleaved schist. The phyllites are indurated to a distance of one or two feet from the junction with the epidiorite.

Messrs. Peach and Kynaston.

In the region between Loch Melfort and the Barbreck River some of the calcareous bands are thick enough to have been wrought for lime, and there seems to be an increase in the thickness of some of the sandy layers, especially near the top of the series. South of Loch Melfort, the members of this series and the epidiorites furnish evidence of contact metamorphism. The impure calcareous bands become calc-silicate hornfels, and in the neighbourhood of the granite, diorite, and felsite bosses, with which the region is invaded, the phyllites and sandy beds become dark, hard, dense biotite-hornfels and the calc-silicates develop pyroxene, though the grade of metamorphism is never so pronounced as that round the Cruachan granite mass.

Near the Point of Degnish, the promontory on the north side of Loch Melfort, the phyllites disappear beneath the black slates and limestones of the Easdale slate group.

Messrs. Peach and Bailey.

*Shuna.*—The Craignish phyllites form about two-thirds of the island of Shuna and are well exposed on its shores. The manner in which lines of sigmoidal fragments of calcareous rock, representing once continuous bands, have been isolated among silky phyllites by folding and strain-slip cleavage is admirably displayed.

On the shores of this island also, the ochreous weathered limestones and calcareous bands, as well as the sandy layers, are well displayed and constantly repeated by folding. Both on the N. and S. shores the junction of these rocks with the black slates of the Easdale series is well seen; the relation of the two groups being shown by the reappearance of the green and grey phyllites of this group on the crests of anticlines within the area occupied by the Easdale slates.

Although these areas are now separated from each other by sea, there can be no doubt that they form part of one great belt, in which these rocks are arranged in a compound anticline, throwing off the Easdale slates both to east and west. In fact they are seen to disappear beneath the slates to the north of the Barbreck River.

Over the whole area these rocks are more or less isoclinally folded, the dip of the axial planes and of the foliation being eastwards at high angles. In Craignish the longer axes of the folds lie nearly N.N.E. and S.S.W., while further to the west the direction gradually veers round, till, in Degnish and Shuna, it is nearly N. and S.

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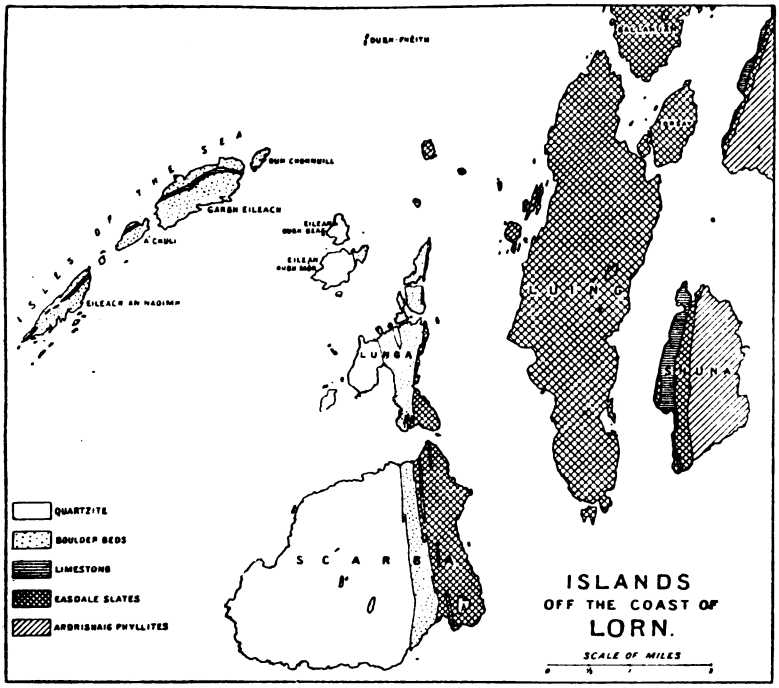


FIG. 3.

As to the horizon of the Craignish phyllite group, there can be no doubt that they are a reappearance of the Ardrishaig phyllites from beneath the great compound syncline, occupied by black schists, limestones, and quartzites, in the Kilmartin area referred to in last year's *Summary of Progress*. Messrs. Peach and Bailey.

## *II.—Easdale Slates and Limestones.*

*Degnish and Shuna.*—As already stated, the passage from the Ardrishaig or Craignish phyllites into the black slates of this group is well seen in Degnish and on the shores of Shuna, where the latter consist of black and grey slates with a few intercalations of thin dark micaceous limestone and some white sandy layers; the series being highly folded. The black slates reappear in folds within the overlying limestones on Shuna, and in places make up its western shore line. The thickness of this group is evidently not great, though no reliable estimate can be given owing to the folding. Messrs. Peach and Bailey.

*Luing and Torsay.*—The strip of Easdale slates exposed in Degnish and Shuna is only the margin of a wide area of sea and land, floored with these rocks, for they reappear in the Islands of Torsay and Luing and in all the islets to the west in the Sound of Luing.

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Messrs. Peach and Bailey.

*Scarba and Lunga.*—Still further west the Easdale slates form a belt of varying breadth along the eastern seaboard of the islands of Scarba and Lunga which is prolonged northwards into Eilean Dubh Mor and Ormsay. In all of these islands they are seen to disappear westwards under the quartzite and to rise on anticlines for a short distance within the eastern limits of these newer rocks.

The black slates are intercalated with lenticular sandy nodules and thin bands of quartzite, which in Scarba and Lunga attain a considerable thickness and sometimes include pebbles of blue quartz. All the rocks of this group are much folded, the strike of the beds and also of the cleavage being more or less N. and S.; while the dip of the cleavage is almost invariably to the E. at high angles. They form the eastern limb of a compound syncline which holds the overlying quartzites of Scarba and Lunga and is prolonged southwards into Jura. The belt is a continuation southwards of that of Easdale and Seil, and along the whole of this zone, workable black slates seem to be better developed than in any other part of the Central or Western Highlands.

*Crinan Area.*—The rocks throughout this area have been thrown into a series of sharp folds trending N.N.E. and S.S.W., so that the Easdale slates and associated limestones are exposed on the crests of anticlines by the denudation of the overlying quartzite. The largest area exposed stretches from the Crinan Canal across Dunardry southwards to the edge of Sheet 36 between Loch Fada and Loch na Brice, where the slates form a compound anticline of a highly complicated nature. Good roofing slates have been worked in two large quarries on Dunardry, and there are the remains of several smaller openings. The dip of the cleavage foliation is at high angles towards the W.N.W. Slates were also extensively quarried in another anticline of these rocks a little to the N.E. of Dunardry on the opposite side of the Canal near Cairnbaan.

*Loch Sween.*—Another anticlinal outcrop, along which these slates have been worked, stretches down Caol Scotnish, a branch of Loch Sween south of Crinan, where they are associated with thin dark limestone; and still other appearances of the black slates and limestones of this group occur in Glen Sabhail and on the extreme west coast.

### *III. Degnish and Shuna Limestone.*

Messrs. Peach and Bailey.

On the west side of Degnish and Shuna the Easdale slates with their intercalated limestones are succeeded by a series of limestones which are dark blue, flaggy and micaceous, near the base, like those of the underlying group. These are overlaid by more massive bands of mottled limestone containing aggregates of black cleavable calcspar, set in a granular calcareous matrix, and alternating with flaggy limestone like the basement beds. Some of the layers, however, are grey and very siliceous and look

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as if they had once been cherts which have been converted into crystalline silica and subsequently traversed by vein quartz. They are involved in the great series of isoclinal folds affecting the underlying Easdale slates and are foliated with the same set of cleavage planes. The limestones have been formerly extensively quarried on Degnish and in Shuna on the most northerly and westerly points. Messrs. Peach and Bailey.

Exposures of similar mottled limestones with black calcite have been observed at various localities in the Kilmartin district, where they are associated with dark limestone and the black schist of the Easdale group. The rocks here were overlaid by a limestone breccia with a more or less sandy matrix filled in with fragments of black schist, limestone and black calcite. The great amount of black calcite in more or less rounded grains, found in the pebbly limestones of the Kilmartin area, is doubtless due to the removal by denudation of a wide-spread area of the limestones of this group, prior to, or during the deposition of, the lowest members of the quartzite.

*Isles of the Sea.* In the extreme N.W. of the district in the Isles of the Sea—a group of rocky islets in the Firth of Lorne—thick masses of limestone and shale form the cores of anticlines, flanked by massive Boulder Beds—the lowest members of the quartzite series. These rocks being fine grained marbles, show signs of contact metamorphism, which affected them prior to their having been overlain by the boulder beds. They are doubtless a continuation to the south west of the limestones of Lismore, previously described by Mr. Muff,* and on the same horizon of those of Shuna and Degnish.

*Evidence bearing on the nature of the surface on which the quartzite was laid down.*

Additional evidence was obtained last season bearing on the unconformability and overlap of the quartzite, on the rock groups already described. In the Isles of the Sea, in the N. W. of the area, the Boulder Beds which there form the local base of the quartzite, are made up in great part of fragments of the underlying limestones, some of which measure eight feet across. To the S. E. in Lunga and Scarba, the local base of the quartzite is a Boulder Bed filled with fragments of the underlying Easdale slates, dark limestones and quartzites, some of the blocks of which are four feet long. The absence of the Shuna limestone from this area is probably due to its removal by denudation prior to the deposition of the quartzite. Near Old Poltalloch in the Kilmartin area Mr. Wilson found, as already stated, a small remnant of the Shuna limestone overlaid by a limestone breccia with fragments of black slate, black limestone and black calcite. In the same district a little further to the N. W. near the head of Loch Craignish, Mr. Muff found, during last season, the following evidence bearing on this unconformability. Messrs. Peach and Bailey.

* See Annual Summary for 1891, pp. 124, 125.

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Mr. Muff. In two or three sections across the strike of the beds, anticlinal folds of the quartzite were noted within which a bed of black limestone appears; whilst the core of the fold is occupied by black slate. Between the black limestone and the quartzite there is occasionally a bed of pebbly limestone. This structure evidently points to a descending succession from quartzite, through pebbly limestone and black limestone to black slate. At least one syncline, exposed in cross section, shows a similar succession. About 400 yards N.E. of Loch Fearphuirn, pebbly grit about ten feet thick, with a thin sandy slate band at the base, rests on four feet of pebbly limestone containing blocks of black limestone. The pebbly limestone in turn rests on black limestone without pebbles, the even bedding of which is marked by numerous thin rather sandy layers. The pebbly limestone with a row of pebbles along its base cuts across the bedding of the black limestone in a manner strongly suggesting an unconformity. In the pebbly limestone 300 yards N. W. of Ormaig, boulders, up to two feet in length, of green phyllite, fine grained grit, hornfelsed limestone and felsite are found. No undoubted boulders of pebbly grit or epidiorite, which rocks are here folded with the limestone, were observed: but some of the blocks of green phyllite resemble the phyllites found in place in Craignish.

Messrs. Peach, Crampton and Bailey. Similar evidence was found in the area south of the Crinan Canal where, however, the Shuna limestone is absent, and where the pebbly limestone and pebbly quartzite—the lowest members of the quartzite—lie directly on the Easdale slates and black limestone. When traced to the S.E. corner of Sheet 36, the quartzite was found to rest directly upon Ardrishaig phyllites, with their characteristic rusty calcareous bands—a fact strongly suggestive of overlap.

Mr. Kynaston. Evidence to the same effect was obtained by Mr. Kynaston in the Loch Awe district, S.W. of Dalmally.

About four miles to the S.W. of Dalmally, and E.S.E. of Inistrynich, the quartzite is seen to rest upon grey phyllites with zones of greyish limestone, in an apparently unconformable manner. The base of the quartzite is here often very coarse and pebbly, and is full of fragments of decomposed limestone, closely resembling that of the underlying calcareous bands.

In the Kilchrenan area, an exposure of the Boulder Bed was examined on the shore of Loch Awe near the manse. It contains numerous boulders of a cleaved pale felsite, not unlike the boulders of felsite seen in the Boulder Bed of the Isles of the Sea. It is associated with a gritty band containing fragments of limestone, and with infolds of narrow bands of limestone and black slate. Boulders of grit are also seen in a dark matrix full of quartz grains. To the south of Achnamady, in the same district, the matrix of the Boulder Bed is in part gritty and in part bears a resemblance to the black slates, and is occasionally laminated. Some of the boulders of dark grey quartzite which it contains are very like the dark quartzite associated with the black slate, exposed in the burn below.

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The quartzite on the north-west side of the Boulder Bed is often full of small fragments of black slate. Mr. Kynaston.

The Boulder Bed is again well seen in the small burn to the west of Kilchrenan, where it appears to rest upon the black slates, and its lower portion is full of fragments of black slate and fine grained quartzite.

The evidence, so far as it goes, appears to be in favour of an unconformity between the quartzite on the one hand, and the black slates and blue limestone on the other; the basement bed of the quartzite being represented by Boulder Bed, pebbly calcareous breccia, or pebbly quartzite.

### *IV. The Quartzite of Jura and Islay.*

Representatives of this group were mapped in several parts of the district. They are most typically developed in the Island of Scarba where the excellent cliff sections display all the zones met with in Jura, which are here given in descending order. Messrs. Peach and Bailey.

5. Zone of flaggy, sandy, and calcareous shales, some of which contain matted and flattened worm-casts, the so-called "fucoids" of older palæontologists.
4. Zone of white and yellow fine-grained quartzite, with small rounded concretions, simulating "pipes" on weathered surfaces.
3. Zone of coarse, false-bedded, massive quartzites, with well-rounded pebbles of pink felspar and blue quartz.
2. Zone of flaggy quartzite with thin dark phyllitic partings, sandy flags and slates, sometimes with worm-casts ("fucoids") and occasional thin sandy dolomitic bands.
1. Zone of pebbly quartzite with blue quartz grains, passing locally into a coarse boulder bed full of fragments of black slate, black limestone, calcareous grit and quartzite, the largest blocks measuring 7 feet in diameter.

Zone 1 can be traced through Scarba, northwards through Lunga to Eilean Dubh Mor and Ormsay; preserving throughout much the same character as it bears on Scarba, and resting everywhere on the Easdale slates. Zones 2 and 3 are also found on Lunga and Eilean Dubh Mor, as well as on Guirasdeal and Eilean Dubh Beag. In Eilean Dubh Mor, however, the small pebbles in Zone 3 measure from two to three inches across, are well rounded and consist of rock fragments such as jasper, quartzite, hardened slate, felsite, and vein quartz, all of which are found in the Boulder Bed of the Isles of the Sea; but no granite pebbles were observed.

Zones 4 and 5 are only met with on the west coast of Scarba, where they are evidently the continuation northwards of the same bands found on the west side of Jura, and described in former issues of the *Summary of Progress*.

In all these islands the rocks are arranged in the same series of overfolds already described, the longer axes of which have a N. and S. trend on the eastern margin of the area; but towards the W., the direction gradually veers round till it becomes N.E. and S.W. On the west side of Scarba the dip of the strata and of the cleavage foliation is persistently to the eastwards.

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Messrs. Peach and Bailey.

These rocks form part of the eastern limit of a great compound syncline, the other side of which is represented by the limestone core exposed in the Isles of the Sea. The grade of metamorphism is very low, the beds showing only a slight cleavage, and in the sandy shales of zones 2 and 5, which often split across their bedding planes, the original clastic micas are still plainly visible. The larger quartz grains of the quartzite show peripheral granulitization, while the finer grains are often entirely granulitized. There is more or less flaser structure and sericite is often found on the cleavage planes.

Messrs. Peach Kynaston and Bailey.

*Isles of the Sea.* In these islands the basement beds of the quartzite is made up of a tumultuous assortment of limestone fragments, many of them well rounded and upwards of eight feet in diameter. Further out from the limestone cores, and presumably higher up in the sequence, the blocks are smaller and the matrix becomes sandy and sometimes black from the presence of much black shale debris. Well rounded boulders, some of them two feet across, of rocks foreign to the island, such as granite, felsite, gneiss, schist, jasper, etc., are scattered through the beds or arranged in groups or nests along certain layers. In places, the beds become so free from included boulders, that they assume the appearance of sandy limestones, which sometimes attain a considerable thickness. These, again, are overlaid by massive sandy dolomitic beds charged with boulders of limestone and rocks foreign to that region. Up to this horizon, the rocks probably all represent zone No. 1 of Scarba; zone No. 2 is represented by sandy shales, bands of sandy dolomite and flaggy fine-grained quartzites, but occasional boulders, both of limestone and foreign rocks, occur throughout the series. This zone is followed outwards by alternations of massive sandy conglomerates, with boulders of limestone and foreign rocks, succeeded by false-bedded quartzites with occasional foreign boulders. These are seen both on the southern shores of the larger islands and in the small skerries that flank them, and probably represent part of zone No. 3 of Scarba. These rocks are arranged in a series of great isoclinal folds, with the long axes running E.N.E. and W.S.W.; the cores of which are occupied by the limestone. Some of the folds can be seen in cliff sections to the height of nearly 200 feet; the dip of the axes of the folds being to the S.S.E. The rocks are so slightly altered that they can hardly be regarded as schists. There can be little doubt that these rocks represent the Port Askaig conglomerate and possibly the Boulder Beds of Islay and of Schichallion in Perthshire. It is also highly probable that the limestone breccia, found by Mr. Muff on the north end of Lismore, invaded and metamorphosed by rocks of the type of the Cruachan massif,* is on the horizon of these basement boulder beds.

Mr. Bailey.

*Crinan District.*—One of the most important results of last season's work has been the successful correlation of the

* Summary of Progress for 1901, p. 125.

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isolated strips of quartzite found on the mainland in the Crinan and Kilmartin districts, with the quartzites of Scarba, and consequently of Jura and Islay; a result due, mainly, to the work of Mr. E. B. Bailey. From the excellent sections exposed in the sea-cliffs extending south from Crinan he has proved that the pebbly basal quartzite is there overlain by a zone of flaggy quartzite with intercalations of silky phyllites, sandy and flaggy shales, sometimes with worm-casts (fucoids), and containing several bands of pebbly and sandy limestone; leaving no doubt that the rocks in this region represent zones No. 1 and 2 of Scarba. Mr. Peach and Dr. Crampton also traced these zones throughout the areas mapped by them. Mr. Bailey.

## EPIDIORITE.

Epidiorite sills of the two types described in the Annual Summary for 1901, p. 120, occur throughout the greater part of the district occupied by the schistose rocks. South of the Crinan Canal they make up nearly half of the surface area, and they are extremely common in the Kilmartin district. They decrease in number in the Craignish and Loch Melfort areas, where, however, there are at least two sills on separate horizons; but they seem to die out westwards and disappear ere the western shores of Degnish and Shuna are reached. A little to the north-west of this line, at least one sill occurs in Torsay and passes a little way south into Luing; but no example was met with over the greater part of the latter island, nor in any of the islands to the west of it, surveyed during last season. Epidiorites, however, occur as well-marked dykes, filling fissures in Scarba and Lunga, in such a manner as to show that they had been injected after the quartzites had been folded and cleaved. While the epidiorite sills everywhere bear witness to having been folded and cleaved with the sediments into which they were intruded, the dykes which obliquely cross the bedding planes of the sediments are partly, or wholly, sheared parallel to their sides, and quite independently of the planes of schistosity affecting the quartzites. These dykes, therefore, although they may belong to the same great period of injection as the sills, must have welled into the fissure at a later date than the period of most intense plication, but while a certain amount of movement was still in progress. They are cut by the porphyrite and lamprophyre dykes, and by the Tertiary dolerites and basalts. The general direction of these dykes is north and south, but a few have a north-west and south-east trend. Most of them are a continuation northwards of those met with in Jura, and described in previous reports. That the movements had not ceased at the time of the injection of the epidiorite dykes in Scarba is shown by the fact that these vertical structures are often abruptly truncated and shifted, sometimes to a distance of half a mile, by a series of thrust-planes which traverse the quartzite more or less parallel to its planes of schistosity, or in other words, to the axial planes Messrs. Peach, Wilson, Kynaston, Crampton, Muff and Bailey. Messrs. Peach and Bailey.

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Messrs. Peach and Bailey.

of the isoclinal folds in which it is arranged. Sometimes several of these thrust-planes, each shifting the same dyke more than its own breadth, may be seen in a single cliff section. Flaser-structures and mylonization seem only to be set up along these planes, which were produced prior to the introduction of the Lower Old Red Sandstone porphyrites and lamprophyres which often follow these lines of disruption, as sills. The porphyrites and lamprophyres have also been injected along the course of the foliated epidiorite dykes, but this is of more frequent occurrence in the case of the Tertiary basalts, which often depart from their course and follow that of an epidiorite dyke for a mile or so, before resuming their original trend.

(*b*) *Area west of Loch Linnhe* (*Sheet 53.*)

Mr. Wilson

In Sheet 53, Mr. Wilson met with granulitic siliceous schists and muscovite-biotite gneiss like those described in last year's report. He followed the main mass of epidiorite in Glen Scaddle across the watershed to the south, where it covers a considerable area, surrounded by its belt of acid gneiss (see former report). He also found to the north of Glen Gour isolated masses of epidiorite with rings of acid gneiss. A new feature in the geology of the region is the occurrence of patches of black and white marble along the margins of some of these intrusive masses.

The region is mountainous and wholly within deer forest, and consequently the population is limited to a few families. The water supply is abundant, particularly that derived from the numerous springs issuing from the epidiorite.

*Sections exposed in Ballachulish Railway Cuttings.* In order to record the geological structure laid bare in the railway under construction between Ballachullish and Connel Ferry, Mr. Wilson traversed that section of it extending from Loch Creran eastwards to East Laroch. The principal points of interest observable are the evidences of increasing metamorphism exhibited by the slates and phyllites as the granite mass of Ballachullish is approached from the east. The granite itself, which is an unfoliated hornblende-granite, near its junction with the schist, is full of small inclusions of biotite schist and banded hornfels. These inclusions also occur in the Ballachullish granite quarry and add to the expense of its working. The junction of the quartzite and limestone with the Kentallenite mass of Kentallen Bay* is also well exposed in the cuttings. Near the contact, the Kentallenite is fine-grained, the quartzite is hornfelsed and the impure limestone is altered into a calc-silicate hornfels.

LOWER OLD RED SANDSTONE.

Messrs. Peach and Kynaston.

*Area north of Loch Melfort.* An area of about 10 square miles of the Lorne Volcanic Series was mapped to the north of Loch Melfort by Messrs. Peach and Kynaston, in connection with the completion of the north-eastern portion of Sheet 36.

*For description of the rock see Report for 1896, p. 22, also paper by Messrs. Kynaston and Hill, *Quart. Journ. Geol. Soc.*, vol. lvi., p. 531.

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The margin of the volcanic series forms a well marked line of crag, well seen to the north of Loch Melfort, and the contact with the older schists is everywhere of a markedly unconformable type. The old surface upon which these flows were poured out was evidently hilly and uneven, and broken into ridges and hollows. This is proved by the gradual rise of the base line of the volcanic series from near sea-level on the east side of Kilchoan Bay, to a height of over 800 feet in the area about An Coire; while the occasional occurrence of inliers at some height within the volcanic plateau serves to mark the site of some of the more prominent ridges of the older rocks. Similiar evidence is afforded in the promontory of Degnish. Messrs. Peach and Kynaston.

The lavas rest directly upon the older schists without the occurrence of any intervening conglomerate, though frequently a thin bed of breccia may be seen underlying the lowest flow. The upper surface of the flows is often slaggy, and flow-brecciation is common. The dip is seldom more than 15°, though occasionally higher angles have been noted. The general direction of inclination is to the north-west.

On the whole the lava-flows of this area are exceedingly uniform in composition. They may all be assigned to the more basic division of the andesites, while some are closely allied to the olivine basalts. There is a complete absence of acid types of lava. The rocks are dark purple, sometimes greyish in colour, sometimes compact, and occasionally highly vesicular. The compact varieties are usually the fresher and often show a well developed flow-structure.

Some of the lavas are evidently closely allied to basalt. Thus a well marked basaltic flow may be traced for some distance to the north-west of Melfort. It is a hard, almost black rock, fine-grained, and closely resembles basalt. Under the microscope (10356) a specimen, from half a mile north of Melfort House, shows numerous more or less idiomorphic olivines, mostly quite fresh and only occasionally altered into serpentine, in a matrix of small plagioclase laths, augite grains, and magnetite. There are no plagioclase phenocrysts and the rock is evidently closely allied to the olivine basalts, though the ground-mass is rather of the andesitic type. This flow is certainly most remarkably fresh for a Lower Old Red Sandstone lava, and there is no other instance in the Lorne area where rocks have been found containing unaltered olivine, though basic lavas, containing numerous pseudomorphs after olivine, are very common.

Fragmental volcanic rocks have only occasionally been met with in this area. A band of about 20 feet of fine-grained reddish ash, occurs to the north-west and west of Melfort, intercalated with the basic flows. A thinner band of similar material may be seen underlying the andesitic crags in the Pass of Melfort.

Between Degnish and Ardmaddy Bay where the rocks of the volcanic platform mark the steep coast line, a bed of decomposing red agglomerate lies near the base of the series. The dip here is seawards, in consequence of which large masses of the

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Messrs. Peach and Kynaston.

piled up lavas, hundreds of yards in extent, have been detached and have slid bodily seawards over the surface of agglomerate, giving rise to very extensive landslips.

Mr. Kynaston.

During the mapping of the volcanic series of south-western Lorne an examination was made by Mr. Kynaston of the basal conglomerates at the north-east end of the Island of Kerrara, and in the area north of Loch Avich.

*North-east end of Kerrara.* Two small patches of conglomerate, formerly mapped by Mr. R. G. Symes, were examined, one at the promotory of Rudh 'a Bhearnaig, and the other slightly further to the E.S.E. near the old burial ground. The conglomerate rests upon an uneven surface of the black schists and is often seen filling cracks. In both of these patches, boulders of granite are very numerous, and are all of the same general type. Further to the south-west a small patch of conglomerate is seen on the south side of Port 'a Bhearnaig, but the granite boulders are not so common. In the rock of Rudh 'Ardan Duinein, no granite boulders could be seen, but boulders of epidosite are plentiful.

The granite boulders vary from a fine-grained pinkish granite or quartz-diorite to a coarse greyish diorite. The coarser varieties are much decomposed. Under the microscope the rocks are seen to be mainly quartz-biotite-diorites, and some are biotite granites with a considerable development of interstitial micropegmatite (10,291, 10,297, 10,298). One specimen shows lines of crushing in a granophyric rock (10,298).

Boulders of the normal basic types of andesite are everywhere common in the conglomerate, associated with the blocks of hornblende-andesite, and some of porphyrite and quartz-porphyry, resembling the rocks which form the later dykes.

*Area north of Loch Avich.* To the north-east of Creag Dubh there are some fine crags of conglomerate containing blocks of andesite, quartz, quartzite, schistose grits, black schist, and epidiorite, and an occasional one of felsite. The epidiorite boulders belong to local types and may range up to 5 feet in diameter. All, except those of slaty rocks, are well rounded. To the south-east of this exposure some conglomerate or breccia is seen resting upon the andesite.

At Creag Dubh a boulder of epidiorite, about 7 feet across, was seen in the conglomerate. At the base of the west side of the crags the junction between the conglomerate and the schists is well seen. It rests upon a sloping surface of fine-grained, greenish chloritic quartzose schists, the surface of which has a smooth and polished appearance, and the junction is perfectly sharp.

Messrs. Peach and Kynaston.

*Volcanic rocks and associated sediments of Glencoe.*—In the early part of June the Glencoe area was visited by Mr. Kynaston, in company with Messrs. B. N. Peach and D. Tait, for the purpose of searching the shaly beds associated with the lava flows, for fossils.

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The result of the examination of the sedimentary bands was the discovery by Messrs. Tait and Peach, in certain zones of dark grey and black shale, of plant remains of Lower Old Red Sandstone age. These were identified as belonging to the characteristic Lower Old Red Sandstone genus *Psilophyton*, and this identification was subsequently confirmed by Mr. Kidston. *Pachytheca* was also found. The best specimens were got by Mr. Tait in a thin band of black shale which occurs associated with purplish, reddish, sandy shales, marls, and conglomerate, at the base of the north-east crags of Stob Dearg, west of Kingshouse. These beds rest immediately upon the upturned edges of the quartzite series, and are overlain by the bedded breccias with gritty bands, which underlie the rhyolitic lavas of the Buchaille Etive Mor. Specimens of *Psilophyton* were also found in a bed of black shale on the south-east side of Stob Dearg, and in a bed of dark grey shales and mudstones, underlying the basic andesites on the north side of Glencoe. Messrs. Peach and Kynaston.

The discovery of these fossils at once settles the Lower Old Red Sandstone age of the volcanic series of Glencoe and the Blackmount, with which the fossiliferous beds are associated, and at the same time intimately connects the Glencoe series with that of Lorne.

## NEWER INTRUSIVE IGNEOUS ROCKS.

### DIORITE AND GRANITE.

*Area south of Loch Melfort.*—In this tract there are many intrusions of diorite, which vary considerably in size. Their mode of occurrence, and the strong resemblance which the rocks bear to one another, suggests that the different exposures are merely the subsidiary off-shoots and protrusions of a much larger underlying mass. Indeed, the relatively large area of contact alteration seen in the surrounding schists, would seem to give considerable probability to this view. Mr. Kynaston.

The largest of the intrusions occupies the highest portion of the ground, and is a roughly oval-shaped mass, being elongated in an east and west direction. It becomes fine-grained at the margin, and decidedly coarser in the more central parts. The exposures often show a good deal of shattering and weathering, the crags often assuming more or less rounded forms. The majority of the hill features are smooth, rounded, and covered with grass and thin heather, while the highest portions of the ground form peaty flats, with occasionally protruding rocky knobs. The ultimate stage of the weathering is a fine, felspathic, micaceous sand, which covers large portions of the area, and often encloses rounded, boulder-like lumps of partially disintegrated diorite. The contact between the diorite and the altered schist which surrounds it, is sometimes clear and well-defined, but is often, on the other hand, of an exceedingly complex nature; the hornfels being traversed by numerous small veins and strings of the igneous rock, or, frequently, portions of the schist have been broken up and floated off by the intruding magma, which, in this way, has produced at its margin a breccia of hornfels fragments in a fine-grained, dioritic matrix.

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Mr. Kynaston.

Occasionally the diorite appears to pass into a variety of porphyrite. Under the microscope, however, there is a sharp distinction between the two rocks. Moreover, the behaviour of some of the minerals in the porphyrite is exactly similar to that of the secondary minerals in certain contact altered igneous rocks, such as andesites, and the phenomena suggest that the porphyrite constitutes an earlier, though closely-related, intrusion, which was subsequently succeeded and altered by the more normal type of the diorite. So that we may probably have in these cases compound intrusions, consisting of an earlier, and sometimes more basic, porphyrite, which was followed by diorite. Dyke-like intrusions and irregular masses of a highly felspathic and more acid material are also sometimes associated with the diorite, and may occur along the margin, or in the more central portion of a mass.

The essential minerals of the normal type of diorite are plagioclase, hornblende, and biotite, together with a somewhat varying proportion of interstitial alkali-felspar and quartz. A pale augite and sometimes also prismatic brown hornblende are not uncommon in the more marginal facies. The biotite is of later formation than the plagioclase and is moulded upon it—a feature which is very characteristic of the diorites of the Ben Cruachan and Glen Fyne areas, and also of Kentallenite. These Kilmelfort rocks are quartz-mica-diorites of the tonalite type, and closely resemble some of the dioritic modifications of the Ben Cruachan granite and the quartz-diorites of the Criffel mass, in the Southern Uplands. The slightly more basic marginal facies recalls the fine grained marginal basic modifications of the Cheviot granite.

There is no field evidence in this area that would define within strict limitations the geological age of these diorities, but it can hardly be doubted that they belong to essentially the same period as the later granitic and dioritic masses of other parts of the south western Highlands, such as those of Ben Cruachan, Ben Nevis, and Glen Fyne, and of the Southern Uplands. All the dioritic masses of this area are accompanied by a contact alteration of the surrounding schists of the hornfels type. As one approaches the diorite, the phyllites gradually pass into the condition of a dark micaceous hornfels, and the calcareous schists are altered into calc-silicate hornfels. A banded hornfels may be produced by the interlamination of these two types. The epidiorite sills also show some alteration. The alteration is of the same type as that observed along the marginal area of the Ben Cruachan granite, and described in detail in the Annual Summary for 1898, though apparently in the present area the alteration is not quite so intense.

Messrs. Peach and Kynaston.

*Loch Melfort Area.*—Dykes and sills closely associated with the larger intrusive masses are of common occurrence in this area, and they are most numerous in the area to the south of Kilmelfort. They vary considerably in size, and consist of different varieties of porphyrites and felsite. In the area occupied

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by the andesitic lavas intrusions of porphyrite are not nearly so common, as they are either to the north-east, or to the south. The normal trend of these rocks is in a general N.E. and S.W. direction. In the area occupied by the schists, sills of biotite-porphyrite are of common occurrence, both to the north and south of Loch Melfort. Sills of a more acid type are also frequently met with. They differ from the normal porphyrites in the rarity of ferromagnesian minerals. Some of them might perhaps be termed felsites, but they are usually so highly decomposed that it is often impossible to tell the character of the original rock. Messrs. Peach and Kynaston.

*Craignish.*—Passing southwards from the granite area into Craignish, the dykes and sills belonging to this series are at first very numerous but gradually decrease in number and size towards the Point of Craignish. The rocks comprise felsites, porphyrites, mica-porphyrites and lamprophyres. They appear between the epidiorite sills and the schists over part of their course, and their trend is therefore in a N.N.E. and S.S.W. direction. Messrs. Peach, Muff and Bailey.

*Shuna, Torsay, Luing, and Islets to West.*—Dykes and sill-like masses of felsite, porphyrite, and lamprophyre occur in considerable number over most of these islands. On the west shore of Luing, N. of Blackmill Bay, some acid felsitic sills may be seen to traverse mica-porphyrites. They usually follow the direction of the planes of schistosity of the slates, which is nearly N. and S. These dykes and sills increase in number and size from south to north; indeed they seem to form a belt distinct from those of Craignish, and may have emanated from a different source. Messrs. Peach and Bailey.

*Scarba and Lunga.*—These islands seem to lie within the same belt of intrusion as that of Luing. Dykes of felsite, porphyrite, and lamprophyre are very numerous near the N. end of Lunga, while they decrease in number southwards. Only a few reach the southern shore of Scarba, and still fewer appear on Jura. Their trend is usually directed by the planes of schistosity, but a few follow the course of thrust-planes and cleaved epidiorite dykes. On the extreme west coast of Scarba they form vertical dykes, which may be seen to cut the quartzites in parallel groups with an E. and W. trend. These are undoubtedly of no great breadth, but are interesting as they exhibit fluxion and spheroidal structures along their edges in a marked manner

*Crinan District.*—In the Crinan area there are only a few dykes of porphyrite and lamprophyre. Their trend is usually N.N.E. and S.S.W., but two were observed to follow lines of crush in a W.N.W. direction.

### TERTIARY INTRUSIVE ROCKS.

The whole district is traversed by a series of dykes, consisting for the most part of olivine-basalts, dolerites, andesitic basalts, and a very few of trachyte and felsite. They are very numerous in the ground on both sides of Loch Melfort, where they traverse Messrs. Peach and Kynaston.



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Messrs. Peach and Kynaston.

the schists, and the Old Red volcanic and intrusive rocks indifferently. In this region they are for the most part basic, some, however, are andesitic, in which case they are often glassy. They are numerous in Craignish, where a good example of a multiple dyke, made up of no less than ten separate intrusions within the same fissure, was observed by Mr. Muff. They decrease in number in the islands to the west of Luing, and only comparatively few are found in the Crinan area. Their general trend is usually N.W. and S.E., but they are often diverted from their course along lines of fault, and of older igneous intrusions such as the epidiorite dykes on Scarba. They were found by Mr. Kynaston to be very numerous in the ground mapped by him in the Loch Scamadale area in Sheet 45, where dykes of trachyte were also recorded. He also found another mass of agglomerate, about 100 yards wide, further south than any previously observed, which probably represents another Tertiary Volcanic vent along the same line of fissure as that mentioned in last year's Summary. (*Summary of Progress*, 1888, pp. 153-154; 1901, pp. 150-151.)

## PLEISTOCENE AND RECENT DEPOSITS.

### *Glacial.*

Messrs. Peach, Kynaston, Crampton, Muff and Bailey.

The whole area mapped in Sheet 36 during last season bears evidence of having been overridden at the period of maximum glaciation by land ice, which moved in a general westward direction.

Small patches of Boulder Clay are found in Craignish and to the north of Loch Melfort and on Luing, but it nowhere covers much of the surface. In Scarba and Lunga the patches of this deposit contain numerous boulders of granite, porphyrite, epidiorite, and schists derived from the interior of the mainland. Boulders of these rocks are likewise scattered over the general surface of all the outlying islands, rocks, and holms.

Only small nests of Boulder Clay, often of a red colour, occur in the Crinan area, many of the included stones being foreign to the district, such as sandstone, porphyrite, and andesite, from which it is clear that the ice which gave rise to the deposit must have traversed an area of Old Red Sandstone rocks. This evidence is in harmony with that obtained in Kintyre, Jura, and Islay.

Traces of moraines were found in the plateaux both to the north and south of Loch Melfort. On the west side of Cruach, Scarba, small moraines cross the hollows emanating from that hill, showing that the island of Scarba must have nursed independent glaciers during the later glaciation. Over the other parts of the district the phenomena are attributable to the earlier and more general glaciation.

### *Rock Basins.*

Mr. Muff.

The four lochans north of Ardfern lie in hollows trending N.N.W., and S.S.E., parallel to the strike of the schists. These hollows are crossed transversely by basalt dykes, which, in nearly

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every case, project above the level of the ground, forming a rocky embankment from 2 or 3 feet up to 40 or 50 feet high, across the floor of the valley. In some cases the dykes are covered by vegetation, but in others the bare rock may be traced from side to side. Mr. Muff.

Since three of the above lochans lie between basalt dykes, which run to the north and to the south of them, there can be little doubt that the lochans lie in rock basins.

### *Raised Beaches.*

Traces of the 100 feet beach either in the form of deposits or of a rock notch were met with along the whole sea-board of the area. The largest development of such deposits was found in Craignish, along the Crinan Canal and south of Loch Crinan. In the deposits belonging to this beach and its sub-littoral zone Mr. Muff found shells (*Littorina obtusa*) at a height of 70 feet above datum level and non-littoral shells in the bed of the Barbreck River a little above sea level in the Craignish area.

Newer beaches at a lower level probably representing the 50 feet and 25 feet beaches make considerable patches of arable land in Craignish and Luing and form a fringe along the low lying shores; while on the rocky shores of the mainland, the outer islands, holms, and skerries, the rock notches representing them are conspicuous features. In one of these deposits in Craignish, Mr. Muff found abundant littoral shells, such as *Littorina littorea, L. obtusa, Mya truncata, Mytilus tenuis, M. modiolus, Tellina tenuis*, and a large species of *Balanus*. In the west of Scarba and other quartzite islands storm beaches of well-rounded quartzite blocks, quite bare of vegetation, accompany each raised beach, reminding one of the west coast of Jura.

### *Alluvium.*

The largest area of freshwater alluvium is found on the Barbreck River at the head of Loch Craignish. Smaller patches of alluvium are found at the bottom of most of the valleys throughout the area but these are often hid under a coating of peat. Some of these alluvia represent silted up lochans, many of which occur in the area south of Crinan.

### *Peat.*

South of the Crinan Canal, peat is found chiefly along the bottom of the deep narrow valleys where schists of sedimentary origin crop out at the surface. It, however, sometimes creeps on to the flat topped ridges. It practically covers the flat tableland south of Loch Melfort and spreads out along the boulder clay and raised beaches in Craignish. North of Loch Melfort it is usually found on the flat topped hills. It also occurs in considerable patches on the islands, especially those consisting of quartzite, where it fills every hollow and even creeps down on to the raised beaches and rock notches.



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### ECONOMICS.

The chief industry connected with the rocks of the region is slate quarrying, which supports a considerable population in Seil, Luing, and Belnahua, as already stated.

Limestone was formerly much quarried and exported from Degnish, Shuna, Luing, Craignish, and the Loch Melfort region, but this has been discontinued.

No very good building stone is found, but the epidiorite sills afford a fairly good material for that purpose, and blocks of considerable size can be obtained, especially where the rock is well foliated. The new hotel at Crinan is built of this material. It is also used as a building stone in Craignish.

Road metal is everywhere plentiful and of excellent quality as the whole country is traversed with dykes of basalt and porphyrite. Quartzite and limestone are also used for this purpose where they are more easily procured than the basalt.

Peat is everywhere obtainable, but owing to the scarcity of labourers and the difficulty experienced in drying the material, it is found cheaper in most places to import coal.

## 2. CENTRAL AND EASTERN ROSS, WITH PARTS OF INVERNESS-SHIRE AND SUTHERLANDSHIRE.

Mr. W. Gunn, District Geologist.
Mr. C. T. Clough, M.A.
Mr. L. W. Hinxman, B.A.
Dr. C. B. Crampton
Mr. E. H. Cunningham Craig, B.A.
Dr. J. Horne, F.R.S. (Acting.)
} Geologists.

The principal formations met with in this district are Highland Metamorphic Rocks, including various gneisses and schists of igneous origin, Granite, Old Red Sandstone, Glacial Deposits, Peat and Alluvium.

### HIGHLAND METAMORPHIC ROCKS.

Mr. Clough and Dr. Crampton

*Deanich District.*—Most of the rocks consist of siliceous granulitic schists of the Moine series, with mica-schists, including biotite-schist, muscovite-biotite-schist, sometimes with grains of secondary albite, and muscovite-biotite-gneiss. The general strike near Meallan Ban and Beinn a' Chasteil is nearly N. and S., but on passing northward from these hills it changes gradually and becomes N. N. E. or N. E., or even E. and W., as on Dunan Liath. The dip—which may merely represent the inclination of limbs of isoclinal folds—is E., S. E., or S., and the degree, which is rarely more than 20 degrees at the western end of Gleann Beag, becomes much steeper eastward, and near Meall a' Ghrianain, the beds, striking N. and S., are often vertical, or in places dip steeply W.

The widest band, in which there is a large proportion of micaceous beds, is a continuation of that mapped last year across Meall an Torcain (near Aultguish). The breadth shows a general

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increase in a northerly direction, from 150 yards on Meall an Torcain to two and a half miles near the head of Gleann Beag. The increase in breadth northwards is accompanied by an increase in coarseness of structure, and by the introduction of thin seams, rich in zoisite and hornblende,* which were not observed on Meall an Torcain. It is hence suggested that the two margins of the band represent one stratigraphical horizon which has been isoclinally folded, and that the wide outcrops northwards, include more horizons than the thin outcrops further south. Mr. Clough and Dr. Crampton.

For some distance E. and S. E., of this broad belt, thin bands of micaceous schist are common. Numerous thin pegmatitic streaks and lenticles, rarely more than a few inches thick, mostly parallel to the foliation and often folded with it, appear in the schists. Even where such streaks occur in adjacent bands of mica-schist they are hardly ever seen in the associated siliceous schists. Besides the folded pegmatites, there are white muscovite-pegmatites sometimes 5 yards broad, which run chiefly along the micaceous schists but frequently act as dykes crossing the bedding in all directions.†

East of the broad micaceous band above referred to, nearly as far as Deanich Lodge, the predominating rock is a blocky siliceous schist, very false-bedded and with the minor laminae often in curves. Still further east, flaggy siliceous schists are met with and occupy most of the long hollow between Deanich and Loch Toll a' Mhuic, and the sides of Gleann Mor. Remains of clastic grains are not uncommon in these flaggy schists, and increase in number in an easterly direction towards Beinn a' Chasteil.

A remarkable siliceous band occupies Beinn a' Chasteil—a hill about two miles south-east of Deanich Lodge, and has been traced for several miles to the north-east. Fully a mile broad, and of uniform lithological character, it is composed of massive beds of a pale pink or white colour, and includes layers in which the original pebbly character is still distinct. Most of the pebbles consist of quartz of a faint amethyst colour, some of felspar, usually ungranulitized, others of a rock resembling jasper, and a few of a composite rock. Lenticular patches, now composed of micaceous schist, and perhaps originally of the nature of "galls," are also common. The summit of Beinn a' Chasteil is in places strewn with small quartz pebbles, some as large as a bean, which have been weathered out of the rock. Near the western margin of the band two thin beds of a silky phyllitic character are seen, and are evidently in a less altered condition than the micaceous schists which occur farther west. Dr. Crampton.

*Augen-Gneiss or Foliated Granite.*—A little S.E. of Crom Loch, and near Carn nan Aighean, is a granitic rock, representing the western margin of the augen-gneiss described in previous

* Thin seams of a similar character, in one-inch Map 92, have been described by Mr. Gunn and Mr. Teall. Summary of Progress for 1897, p. 41.

†This series of dyke-like pegmatites is a continuation of that described on Creag Rainich in the Summary of Progress for 1902, p. 107.

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Dr. Crampton.

Summaries. The margin of the main mass is irregular, and outside it there are small portions of similar rock entirely surrounded by schist, but in general the strike of the schists is nearly parallel with the margin of the foliated granite. The schists are somewhat altered for a distance of about half a mile, but, owing to the almost complete absence of argillaceous sediments, the alteration is less evident than in the Kildermorie area.* The granitic rock varies in grain considerably. Some varieties are without any distinct foliation and contain large beautifully zoned felspars and pea-like blebs of bluish quartz; others are well foliated and closely resemble the augen-gneiss of Inchbae. Angular and rounded masses of more basic material, varying in length from an inch to several yards, appear within the augen-gneiss. Close to the margin, however, these basic inclusions do not seem to occur, though lenticles of schist are not infrequent. The basic inclusions vary considerably in composition, some consist chiefly of hornblende while others are less basic and contain blebs of blue quartz like those in the granitic rock. Most of the basic inclusions are unfoliated, but some are crossed by a foliation in the same direction as that in the enclosing acid material.

Mr. Clough and Dr. Crampton

In most of the area, thin bands, evidently intrusive and chiefly composed of hornblende-schist, chlorite-schist or biotite-schist, are rather common. Some of these run nearly parallel with the bedding, others behave as steep dykes or sheets making a small angle with the horizon. In many cases the foliation is in the same direction as that in the adjacent schists, in others it crosses the margins; but in certain bands which show their intrusive origin most clearly, it is parallel to the margins, and not in the same direction as that in the adjoining schists. This fact, combined with the poor development of foliation in certain cases, and the occurrence of some sections in which the schists of sedimentary origin are seen to have been folded and subsequently cut by the intrusive rock, renders it probable that some of the bands referred to were not intruded until after the sediments were already in a schistose condition.

Besides those bands of intrusive origin which are generally schistose throughout, there are some which are only foliated in exceptional cases, generally near the margins. These recall the foliated lamprophyres, and some are certainly of later age than the adjacent more foliated intrusions.

Mr. Clough and Dr. Crampton.

*Craigs District.*—Siliceous schists of the Moine series form most of the area. No bands with such large pebbles as those on Beinn a' Chasteil have been observed, but some in Garbh Allt about two thirds of a mile W.N.W., of Cnoc an t' Saic, and probably on the strike of those on Beinn a' Chasteil, contain pebbles which in their deformed state are an inch long. The strike is generally E.N.E., or E. and W., and the dip S.S.E., or S., often at 60° or 70°. On the south side of the main mass of siliceous

* See Summary of Progress for 1901, p., 108.

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schist there is a band, often more than half a mile broad, which contains a large proportion of muscovite-biotite-schist and also patches of hornfelsed rocks. The schists in the south portion of the band are usually mixed with irregular sheets and bands of granite rock, now generally foliated and in the form of augen-gneiss, which form a fringe round the northern edge of the great mass of augen-gneiss of Abhuinn Shalachie and Carn Salach. The muscovite-biotite-schist is frequently garnetiferous, and closely resembles the broad band already described near Glenbeg and Toll Lochan (Deanich district); containing, like the latter, thin seams rich in zoisite and hornblende. It seems possible, therefore, that the two bands may belong to the same stratigraphical horizon. Mr. Clough and Dr. Crampton.

The hornfelsed rocks, and those granitic rocks which show little or no foliation, are in places crossed by thrust planes and are much altered near them, the hornfelsed rocks being converted into mica schists, and the granitic rocks into augen-gneisses with a fine granulitic matrix. A fuller account of these thrust planes, etc., is given elsewhere.* Mr. Clough

In this district no basic lumps have been observed within the granitic rock, but there are several bands of later dark basic rock, partly schistose and chloritic, which traverse the foliated granite and the altered sediments associated with it.

Thin bands of hornblende-schist and chlorite-schist, of intrusive origin, are common in the river Carron and Garbh Allt.

*Loch Glass District.*—The schists in this area belong to the Moine series and are associated with pegmatites and foliated epidiorites and hornblendites. The dip is S.W. or S.S.W. at angles varying from 15° to 60°, and the strike is generally constant. The broad band of muscovite-biotite schist already described on the south-west shore of Loch Morie, extends across Meall Beag to the side of Loch Glass, where it is more than half a mile broad, without any admixture of quartzose schist. On the west side of this band, quartzose schists appear, but the area to the east, as far as Meall an Tuirc, is chiefly occupied by alternations of blocky quartzose schist, rather micaceous flaggy schist and muscovite-biotite-schist. In the rapid alternations east of Meall Mor are a number of white pegmatites like those at Garve, which contain large crystals of muscovite and garnet; in these alternations also appear the foliated epidiorites and hornblendites. They are generally in the form of sills, often contain garnets, and sometimes inclusions of schist. The foliation-planes in certain muscovite-biotite-schists, near the shore opposite Culzie Lodge show elongated rod-like bodies which are perhaps pseudomorphs after andalusite. Dr. Crampton.

*Area North-East of Loch Garve and the Blackwater.*—A broad well-defined band of coarse muscovite-biotite gneiss crosses the lower end of Loch Garve, and forms the rocky ramparts of Creag Rogaidh. The rock is often intensely crumpled and Mr. Hinxman.

* See Appendix, p. 150.

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Mr. Hinxman. overfolded, and in places contains thin bands of very siliceous material. On the south side of the railway the ground east of the Blackwater is entirely occupied by siliceous Moine schists. Garnetiferous amphibolite is associated with these rocks in many short interrupted sills, but it is not so largely developed as on the west side of the Blackwater.

Mr. Hinxman. *Strathconon Forest.*—The ground is chiefly occupied by the two chief members of the Moine series, the Moine siliceous schists and muscovite-biotite gneiss.

The Moine siliceous schists include highly siliceous bands which may be described as granulitic quartzites, but in which a small amount of biotite in minute specks is always present. Signs of considerable movement are frequent in these rocks, and are shown by "rodding"—the drawing out of the mineral particles in one determinate direction,—and the special development of secondary white mica on the foliation planes.

The most interesting feature of the work in this area has been the recognition of two belts or infolds of granulitic acid and hornblendic gneiss, similar in character to granulitic types of Lewisian gneiss found in the north-west Highlands.

The westernmost of these infolds enters the map on either side of the river Orrin, forming an irregular and interrupted belt about three miles in breadth. The gneiss is here associated with the most siliceous type of Moine schist, with which it is so intimately interfolded that it is often difficult to separate the acid portions of the gneiss from the quartz-granulites. The former is, however, more felspathic, and can generally be distinguished from the latter by its banded appearance and mode of weathering.

Rocks of more basic type occur in rapid alternation with the acid gneiss, and include biotite and biotite-hornblende gneisses, and also a rock in which pyroxene and green amphibole are the predominant minerals, with thin parallel folia of quartz and secondary felspar. A lenticular band of ultra-basic rock containing serpentine after olivine, and pale green hornblende injected with serpentine along its numerous fissures, is associated with these Lewisian rocks in the valley of the Orrin. It is for the most part concealed beneath the river alluvium. On the north side of Carn na Creadha there is a small exposure of pyroxene-hornblende rock which is apparently an altered pyroxenite or peridotite.

The second infold crosses the valley of the Orrin between Tighcoirechairbhe and Corriehallie Lodge. It is about three and a half miles in length, a mile in greatest breadth, and lenticular in shape, thinning out rapidly to north and south, where the extremities are concealed beneath peat mosses. At the eastern edge of this inlier the gneiss is almost entirely of the acid variety, but passing inwards it becomes more and more mixed with bands rich in biotite and hornblende, and in the centre of the fold the acid and basic types alternate rapidly with one another.

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Bands of black or dark green hornblende rock, some of which reach a breadth of 30 to 40 yards, can also be traced nearly throughout the area from north to south of this second infold. These bands are thoroughly foliated with the gneiss, but it is possible that they may represent basic dykes intruded into the original complex before the present foliation was produced. The Lewisian gneiss is, at one point only, brought into contact with the muscovite-biotite gneiss, by a N.E. and S.W. fault which crosses the river Orrin and has determined its course for 300 yards. Elsewhere, north of the Orrin, the two rocks are always separated by a narrow belt of siliceous Moine schists. In the southern part of this inlier, and also in that to the west, the intervening area of siliceous schist varies greatly in extent, from less than a quarter of a mile to more than a mile and a half. This discrepancy in the relations of the boundaries of the two infolds to those of the members of the Moine series, may be due in part to folding, but it suggests the effect of overlap accompanying an original unconformity between two formations. **Mr. Hinxman.**

*Glen Urquhart District.* The greater part of the area surveyed is occupied by rocks of the Moine series.

A zone of muscovite-biotite gneiss associated with kyanite gneiss and a much mineralised limestone runs S.E. from the neighbourhood of Loch Gorm. **Mr. Cunningham Craig.**

A large mass of foliated serpentine occurs in the schists, intruded subsequently to their folding but prior to the later shearing movements. There are also some small intrusions of an older granite rock and pegmatite, later in time than the folding, which have been greatly deformed. The granitic rock now appears as a well foliated garnetiferous muscovite gneiss, of very acid composition. The pegmatites are perhaps less sheared than it, but are almost entirely granulitized.

## OLD RED SANDSTONE.

*Deanich District.*—In the outlier of Old Red Conglomerate on Meall a' Ghrianain some of the boulders of augen-gneiss measure about seven yards across. It has now been proved that augen-gneiss occurs *in situ* much nearer this hill, on its east side, than was formerly supposed. Indeed, a small outlier of similar conglomerate, probably originally continuous with that on Meall a' Ghrianain, has been found about a quarter of a mile N.N.W. of the cairn of Carn nan Aighean, where, at its eastern end, it rests on augen-gneiss. **Mr. Clough and Dr. Crampton.**

On the western slopes of Meall a' Ghrianain there are a few small patches of breccia made of siliceous schist, like that on which they rest or abut. Some of these may possibly be crush breccias, but at least two of them seem to represent broken up schist-surfaces of irregular form, and they are probably of Old Red Sandstone age.

*Area N.E. of Loch Garve and the Blackwater.*—Half way down the steep hillside that rises above the northern slopes of Loch Garve there occur two small isolated patches, separated by a **Mr. Hinxman.**

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Mr. Hinxman. stream, of a curious breccia made up of angular fragments of the surrounding muscovite-biotite gneiss. Both the breccia and the underlying gneiss are pierced by an intrusion of mica-trap or lamprophyre, which contains numerous fragments of both rocks, and appears to have altered and hardened the matrix of the breccia. If this breccia form part of a local basal breccia of Old Red Sandstone age, it is difficult to account for its position, except on the hypothesis that the breccia was laid down on an extremely uneven surface, and that it has been preserved in this locality in consequence of the induration induced by the igneous intrusion.

Mr. Cunningham Craig. *Glen Urquhart District.*—A considerable thickness of Old Red Sandstone overlies the Moine gneisses. The pebbles in the conglomerate beds are almost entirely of local origin.

Dr. Horne. *District of Dores, Loch Ness.*—On the east side of Loch Ness, a small area of Old Red Sandstone was mapped, extending from the shore of that loch east to Loch Duntelchaig. An interesting feature is the development of the basal conglomerate on the moor west of Duntelchaig, and on the prominent ridges of Creag Bhreac, and Creag Bad an Eich near Achnabat. At certain localities the bedding is not apparent, but on Creag Bhreac it can be made out by means of thin sandy intercalations and by the parallel arrangement of the pebbles. The mass there dips to the north-west at an angle of about 10°. On that crag and on the moor to the north-east the conglomerate is traversed by small faults, running in a north-west direction, which have fractured and crushed the pebbles. The latter consist mainly of quartz-schist, flaggy granulitic gneiss, mica-schist, pegmatite, granite, porphyrite, and quartz-porphyry. Indeed, the striking characteristic of the mass is the abundance of pebbles of quartz-porphyry and porphyrite, closely resembling some of the apophyses of the newer granite.

The conglomerates pass upwards into red grits with scattered pebbles and sandstones, exposed on the north-west side of Loch nan Eun Rudha and south-westwards to the farm house of Drummond. A thin representative of the well-known fish-band, consisting of shale with small limestone nodules, has been detected at one locality, viz., on the north west shore of Loch Nan Eun Rudha, where it is apparently intercalated in the grits and sandstones. Next in order come reddish hard grey sandstones, often falsebedded, visible in the Dores Wood, where they dip to the north west at angles from 15° to 35°. In the lower part of the Drummond Burn (Allt da Linne) they are associated with calcareous flagstones and shales.

## PLEISTOCENE AND RECENT DEPOSITS.

### *Glacial.*

Mr. Clough and Dr. Crampton. *Deanich District.*—Though there are a few boulders of augen-gneiss on the west side of Meall a' Ghrianain, no boulders either of this rock or of the pebbly grit bands, a little west of it, have been observed in the drift on the west side of Beinn a' Chasteil,

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nor do any pieces of augen-gneiss seem to have been carried west of the margin of this rock near Crom Loch and Carn nan Aighean. Here then the ice-movement seems to have been towards the east. Mr. Clough and Dr. Crampton.

The striæ in Gleann Beag run nearly east almost in the direction of the glen. But on the higher ground north of the glen the striæ are N. or N.N.E.

Morainic drift fills all the principal hollows, and is also found on some of the high plateaux between the glens. Groups of moraines of large size occur in the low ground north of Loch Toll a' Mhuic.

A great part of the high plateaux is covered by a wide spread smooth-surfaced deposit which is evidently in the main of local origin, and which often gives good evidence of the rock *in situ* beneath it. It is of considerable thickness on some slopes, and is difficult to separate from drift of undoubted glacial origin. In many places it is now arranged in a series of small terraces, caused by small slips, or soil cap motion, since it was first formed.

Peat covers most of the low ground formed by the augen-gneiss and large portions of the high plateaux formed by the schists. It often contains stools of Scotch fir (*Pinus sylvestris*) in great abundance, and in some cases at heights of 2,000 feet.

*Craigs District.*—No boulders of augen-gneiss have been noticed on the low hill slopes on the south side of the river Carron, but they are common in the bed of the river; many having evidently been carried down in recent times by burns running northward from the gneiss. The ice carry was generally E. or E.N.E., as indicated by the striæ both on Cnoc an t' Saicd and the northern slope of Carn Salach and other places. Dr. Crampton

*Loch Glass Area.*—The morainic drift near the road at the south end of Loch Morie contains lenticles of contorted yellow ferruginous sand. A small patch of morainic drift along the N.E. shore of Loch Glass, near the foot of the loch, contains a number of boulders of augen-gneiss. Nearly a mile above the foot, and a few hundred yards from the edge of that loch, a small boulder of conglomerate belonging to the Old Red Sandstone formation was noticed on the surface. This boulder is fully a mile from Meall an Tuirc—the nearest point at which such conglomerate is at present known to occur *in situ*—and should it have come from there, it must have been carried in a direction exactly opposite to that of the main ice-flow in this area. It may, however, have come from some exposure not yet surveyed to the west of Loch Glass.

*Meall na Speireig Area.*—Except on Meall na Speireig, the solid rocks are almost entirely hidden under drift, and splendid sections of drift occur in the banks of Allt nan Caorach. It is of a pale yellow or red colour, and full of rounded boulders of schist, pegmatite, augen-gneiss and a basic igneous rock not known in the district. Stratified lenticles of yellow sand are in places involved in the drift. Terraces, at heights of about 30,

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Dr. Crampton 50 and 70 feet above the present bed of the river, and corresponding to terraces previously mapped by the late Hugh Miller,* occur near the junction of the Allt nan Caorach and the burn which flows N.E. from near Cnoc nan Each.

Peat covers the whole area except a few patches on Meall na Speireig and a thin strip along Allt nan Caorach. In one small burn it is at least 8 feet thick, and contains three super-imposed layers of Scotch fir (*Pinus sylvestris*) stumps apparently in position of growth.

Mr. Hinxman *Strathconon Forest.*—A fine series of moraines sweeps up the valley of the Rogie Burn to the summit level of the Dingwall and Skye Railway at the Eagle Arch. Carried boulders of the Inchbae augen-gneiss are plentiful along the valley, and the trend of the moraines and direction of striæ indicate an ice movement between E. and E. by S.

At the bottom of the valley and near Loch Garve the moraines are composed of gravelly material, and seem to merge into the high lake terrace which is well marked on the north side of the loch as far as the farm of Rogie.

The upper part of the Orrin valley displays a succession of parallel, terraced, lateral moraines which can be traced along the south side of the glen up to a height of 2,000 feet, or more than 1,000 feet above the level of the river.

Dr. Horne. *Dores District. Loch Ness.*—Numerous striæ were observed on the dip slope of conglomerate on Creag Bhreac and north-eastwards along the moor to Loch Ashie where the trend varies from N.E. to E.N.E. and E. 13° N. Indeed the evidence confirms the conclusion which has long been formed that the trend of the ice as it issued from the Great Glen veered from N.E. to E.N.E.

Excellent sections of boulder clay are visible in the Drummond Burn and in some of the streams draining Dores Wood. Moraines, in the form of conical mounds and long sub-parallel ridges strewn with boulders, are to be met with on the moor between Loch Duntelchaig and the south end of Loch Ashie. Very large boulders of Old Red Conglomerate with the characteristic pebbles of quartz-porphyry and porphyrite, derived from the prominent crags at the south-west end of Loch Duntelchaig, are thickly strewn over the ground to the north-east.

On the slope between Loch Ashie and Loch Ness there is a series of parallel strips of peat and alluvium, ranging from a quarter to one mile in length and from 25 to 100 yards in breadth, which run along the strike of the sandstones, that is north-east and south-west. On their north-west side there is an escarpment of sandstone, and towards the south-east there is a dip slope of sandstone partly covered with drift. It is probable that these strike hollows may have been

* Mr. Hugh Miller noticed that the terraces were in part bounded by a lower morainic area, which he supposed to have been occupied by ice at the time of their formation.

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deepened by ice action, for at certain localities striæ are found on the dip slopes pointing in a north-easterly direction. Dr. Horne.

On the shores of Loch Ness near Dores there are traces of the 50-feet and 100-feet sea beaches.

PHYSICAL AND ECONOMIC FEATURES.

The Deanich District is entirely in deer forest, and has few inhabitants. It contains a large extent of high ground in the form of broad plateaux, separated by deep glens and indented by rocky corries. The elevation of the plateaux gradually increases in a westerly direction, and near Meallan Ban, and the head of Glenbeg and Coire Mor there is a considerable extent of ground more than 2,500 feet high. The Craigs area consists almost entirely of heathery and peat-covered grouse moor and sheep ground, of moderate elevation; the highest point, on Carn Salach, being only 2,118 feet. A scanty crofting population lives near the Carron, and cultivates the alluvial flats of that river. The water for domestic use is usually procured from the small streams which flow into the river. Mr. Clough and Dr. Crampton

*Strathconon Forest.*—This is a wild mountainous region with summits rising to upwards of 3,000 feet, and deep glens and corries that carry snow far into the summer. It is entirely given up to grouse and deer, and contains no signs of human occupation save a few solitary keepers' houses, each with its tiny patch of cultivation on the river haugh. The lower portions of the hill sides are ice-worn, bare and rocky, but on the flatter summits and upper slopes there is often a fairly thick covering of drift, as well as wide peat mosses of considerable depth. Mr. Hinxman

The alluvial flats along the upper course of the Orrin are grassy or peat covered. To these peaty flats the deer resort in the spring to crop the young shoots of the cotton grass (*Eriophorum*), on which deer and sheep are said to thrive after the winter better than on any other natural food.

*District of Dores, Loch Ness.*—In the lower raised beach west of Dores Church there is a deposit of fine clay which is now used in the local pottery works. Dr. Horne.

## 3.—East Highland District.

Dr. J. Horne, District Geologist (Acting).

Mr. G. Barrow
Mr. L. W. Hinxman, B.A.
Mr. J. S. Grant Wilson
Mr. Kynaston, B.A.
Mr. E. H. Cunningham Craig, B.A.
} Geologists.

HIGHLAND METAMORPHIC ROCKS.

*Gaick Forest.*—In the tract mapped by Mr. Barrow which lay to the south of Gaick Lodge, the parallel banded Moine gneisses are typically developed. The colour banding of the gneiss has a persistent dip to the north at angles varying from 5° to 20°, Mr. Barrow.

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Mr. Barrow. in an opposite direction to that observed in the Garry area. As in the latter district, all but the more massive and less banded varieties contain much microcline, showing the typical cross hatching, and this mineral is specially abundant in the types rich in brown mica, which must have been originally of a more shaly nature. There is here one small band, usually containing epidote or some other lime-silicate, and generally small garnets, also noted in the Garry area, which, from its frequent repetition by folding, suggests that the series is of no great thickness.

Numerous veins of granite and pegmatite traverse the gneisses of this region. From the evidence in the area examined by Mr. Barrow, he infers that they belong to three groups, derived probably from different magmas; each group having apparently a different trend.

The first type, the product of the biotite-granite magma, is unfoliated and is represented by a few thin veins in the eastern part of the ground, where they are undoubtedly cut by the pegmatites of the second series. The latter belong to the biotite-muscovite magma and are represented in the middle portion of the Gaick Burn by a number of veins of associated granite and pegmatite, often of considerable thickness and occurring in groups which trend in a S.S.E. direction. These veins decrease in number and size to the south, east, and west of the Gaick Burn. The occurrence of pegmatite, either in the middle, on one side, or on both margins of a vein is interesting, as it suggests that the material has not been forced out as so constantly happens in other areas. This feature may be due to two causes. First, the highly crystalline condition of the Moine gneisses suggests that the temperature may have been so high that rapid consolidation could not take place. Indeed the final cooling may have proceeded so slowly that segregation was possible *in situ*. Second, the unbroken condition of the colour bands of the gneisses suggests that the latter entirely escaped the crushing action so often met with in the more southerly areas. Hence the granite material may have escaped the dynamic action in this area, or the forces may have ceased before the consolidation began.

The third series consists entirely of muscovite-pegmatite veins which trend in an east and west direction, and steadily increase in number and size to the west. They are the typical unfoliated pegmatites derived from the muscovite-biotite-gneiss magma, described in a communication to the Geological Society of London in 1893 by Mr. Barrow.* These intrusions are cut by a series of faults which do not affect the far more recent granite masses.

The rocks belonging to the newer granite consist of dykes and sills of acid, intermediate and basic material; but by far the most important constituents of this group, in the Gaick area, are the sills or horizontal sheets of quartz-porphyry. These sheets, which vary in thickness from 20 to 50 feet in the area surveyed by Mr. Barrow, are rather pale in colour and very acid, with crystals of quartz. Their edges are fine-grained, and their

* *Quart. Journ. Geol. Soc.*, vol. xlix. p. 330.

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mode of occurrence suggests an approximation to the nearly horizontal sheets of quartz-porphyry of Tertiary age in Eigg. In other words, in place of showing deep-seated phenomena like the granite veins they suggest an approximation to the volcanic conditions seen in the lower shales of that island. Mr. Barrow.

The lamprophyres also, have in places a sill-like mode of occurrence and often present a point of special interest. It is clear that over a very large area the newer granite intrusions were contemporaneous with an epoch of considerable faulting, and these faults in this district often bend over and become minute thrusts inclined at a low angle. The lamprophyre sills sometimes occur along these planes, in which case they present on their margins either a sheared aspect or a preconsolidation foliation. This fact is of importance, because the lamprophyre intrusions are so clearly later than the crystallisation of the Moine-gneisses that their foliation can not in any way be connected with the movements concerned with the production of these gneisses. The two are clearly separated by an interval of great faulting.

In the tract mapped by Mr. Kynaston which lay to the west and south-west of Gaick Lodge, the schists of Moine type consist mostly of banded quartzo-micaceous granulitic rocks, fine to medium-grained, and frequently flaggy and with bands rich in biotite. Some parts are more massive and quartzose, while others again are highly felspathic. The dip of the limbs of the folds is seldom higher than about 15°, and frequently these are seen to be lying almost flat, as, for instance, in many of the crag sections. The sharp isoclinal type of folding may sometimes be observed to the west of Loch an t' Seilich. Folded and puckered quartz veins are also fairly common in some places, and appear to be older than the period of the folding of the area. A mottled band, a few inches thick, showing small patches of ferromagnesian minerals and some epidote, was traced for some distance on the west side of Loch an t' Seilich and on the west side of Bogha-Cloiche. Mr. Kynaston.

The greater portion of the area surveyed is seen to be traversed by numerous veins of pegmatite and fine-grained granite. The pegmatites usually consist of a coarse aggregate of pink felspar, quartz and muscovite. Biotite-pegmatites, without any muscovite, are also occasionally met with, and sometimes in the smaller veins there is an entire absence of mica. The coarse muscovite-pegmatites always constitute the larger veins and sometimes attain a breadth of 7 or 8 feet. They traverse the schists in almost any direction, and frequently lie parallel to the banding.

Small veins of granite are also exceedingly common, especially to the west of Gaick Lodge, and gradually become fewer in number further to the south. They consist of fine to medium-grained pinkish or greyish biotite-granite. The proportion of biotite varies considerably, and there is sometimes also a little white mica present, and occasionally the veins are rather of the aplite type. They vary in size from a few inches up to 5 or 6

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Mr. Kynaston.

feet in breadth. They are closely associated with the pegmatites, the granitic material being sometimes interbanded with pegmatite, or the granite vein may show a central portion of pegmatite, or again pegmatite may occur along the margin of granite. The pegmatites also occasionally cut the granite veins.

Sills of quartz-porphyry are very numerous to the west and north-west of Gaick Lodge. They appear in most cases to lie almost horizontally and may attain a thickness of 40 or 50 feet. They become compact at the margin, where they also often show a platy structure due to flow. They belong to the Glen Tromie type of quartz-porphyry, and show phenocrysts of idiomorphic quartz, felspar, and frequently biotite, in a pale pinkish felsitic or microcrystalline matrix. The proportion of phenocrysts to groundmass varies considerably.

Besides these sills of typical quartz-porphyry, there are also some red felsites, which behave rather as dykes, and these are seen sometimes to cut the quartz-porphyry sills. They usually show no conspicuous phenocrysts to the naked eye, though sometimes, as in the rock of Creag Dearg, 1½ miles South West of Gaick Lodge, small felspars and quartz grains may be recognised. A well-marked flow structure may often be observed along the margins of these intrusions, occasionally accompanied by parallel bands of small spherulites.

Intrusions of lamprophyre are fairly common, though, perhaps, somewhat local. They are mostly fine or medium-grained dark greyish and greenish hornblende-lamprophyres, though considerable variations occur. Some of the coarser types appear on the east side of Sgur Dearg, west of Gaick Lodge, and in the south-west part of the area, especially on the west side of Loch an Duin. The lamprophyres usually behave as sills, though sometimes as dykes. Sometimes hornblende is the predominating ferromagnesian mineral, and sometimes biotite, the more felspathic types usually being richer in biotite.

One of the sills apparently belonging to this group, about 10 feet in thickness and occurring about one mile west of Bogha-Cloiche, west of Gaick Lodge, is cut by several small pegmatites and by a coarse muscovite-pegmatite, of about 3 feet in width. In one place the lower portion of the sill passes into a fine-grained biotite-granite. The upper and central portions are decidedly more basic and consist of biotite and prisms of green amphibole in a felspathic matrix, which shows under the microscope a large proportion of microcline. The structure recalls that of some of the syenitic lamprophyres associated with the newer granites of Argyllshire. If this rock is of newer granite age, the pegmatites which clearly cut the sill cannot belong to an older period.

Mr. Cunningham Craig.

In the eastern part of the Forest of Gaick Mr. Cunningham Craig obtained evidence which enabled him to subdivide the Moine gneisses into certain lithological zones.

To the east of Loch an t' Seilich and Gaick Lodge there is a line of cliffs and steep crags, affording a continuous section about two miles in length and from 750 to 1,300 feet in height; the

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lower part being often masked by screes. The section runs approximately north and south at a slight angle to the strike of the beds and the folding, and it is thus possible to trace out each bed or fold along the cliff faces, and to measure approximately the throw of faults which cut the line of section. Mr. Cunningham Craig.

The folding is flat and perfectly isoclinal, with the overfolds towards the west and north-west as a general rule, so that it is only when the crest or trough of a fold is approached that the folding can be recognised, but there is very little repetition of the beds on a small scale, such as is common when the flexuring is shallow. The folds are large and deep though lying almost horizontally, and there is no superposition of one fold in a bed directly above another fold in the same bed. Hence it follows that in ascending the section, different zones are exposed in sequence, while here and there one of the great folds repeats a portion of the series.

Four zones can be distinctly made out and recognised by their lithological characters in this section; but whether in ascending or descending order, remains to be proved:—

(1) Thick bedded quartz-biotite-gneisses, containing little felspar, and with a very homogeneous, granular, and very slightly foliated appearance on cross fracture. Muscovite is either entirely absent, or present only in very small quantity. This is apparently one of the thickest of the zones, but only a small part of it is seen at Gaick. The rocks of this zone make the best building stone, and generally form bold crags, broken by joints into large square-edged slabs and blocks.

(2) Very thin-bedded, rusty-weathering felspathic schist or gneiss, containing much felspar, and weathering consequently into round-edged and crumbling flakes or slabs. The biotite is not abundant, and is chiefly concentrated along the surfaces of the beds, rather than distributed throughout the bed, forming there a glistening felt, usually accompanied by a proportion of muscovite.

About the junction of zones (2) and (3) a very characteristic mottled band occurs. It is usually 3 or 4 inches thick, and consists of a granular aggregate of quartz and felspar with little mica, containing darker spots or interrupted folia, elongated parallel to the bedding. The latter, when crushed and examined under the microscope, are seen to consist chiefly of epidote and hornblende, with some garnet and zoisite (?). There may be more than one band of this nature at this horizon, but one band at least has been recognised in many localities, in spite of its thinness.

(3) This zone resembles zone (1) in composition, but is not so thickly bedded. It consists of flaggy, quartz-felspar-biotite-gneisses. On a cross fracture the rocks of this zone present a granular arrangement of the constituents, while on bedding planes a felt of both black and white mica is common. There is rather more biotite disseminated through the beds than in zone (1). Under weathering processes the rock breaks up along joints into large rectangular or triangular slabs.

(4) This zone, which is more largely developed than either of the two preceding sub-divisions in the Gaick ground, consists of fine-banded and thin-bedded felspathic gneisses, containing less biotite and more muscovite than the preceding zones. On a cross fracture a finely granular aggregate of quartz and felspar with some mica, not well orientated, is observed, the appearance being almost granitic in character. Felspar is very abundant, and frequently gives a pink colour to the cross fracture, but the soft, rounded, and rusty weathering of zone (2) is never seen; the rock breaks up into sharp angular fragments, which retain their angularity even when reduced to fine rubble. Felts of mica upon the bedding planes are not common.



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Mr. Cunningham Craig.

The four zones described above have been identified and recognised from the Eidart in the east to the Truim in the west, and from Glen Tromie in the north to the neighbourhood of Dalnaspidal in the south. Only in very good sections, however, can they be mapped out with any degree of accuracy. Several other types of rock have been observed in neighbouring areas, but their relations to the above zones have not been established.

The thickness of the gneisses exhibited in the Gaick section alone, after making due allowance for repetition by folding, is not less than 200 and not more than 400 feet.

The ground surveyed in Glen Tromie and the Forest of Gaick is remarkable for the number and variety of the igneous intrusions belonging to the newer granite and diorite. These may be divided roughly into plutonic rocks and dyke rocks, but the distinction is an arbitrary one, as not only every type from a coarsely crystalline pegmatite to a fine spherulitic felstone may be seen among the acid rocks, and an actual passage from a granite to a quartz-porphyry has been observed in more than one locality. Among the rocks of intermediate composition, also, the type varies from fine diorite to the most compact lamprophyre.

The acid intrusions of plutonic type are never of great size; they are the continuation of the veins of granite and pegmatite of Glen Feshie (*Summary of Progress* 1901, pp. 165–166), and as a general rule, increase in number and coarseness of grain when traced towards the Cairngorm and Meall Tionnail granite masses. In the Gaick area the veins consist of granite, aplite, and pegmatite, the two former being usually fine in grain. The pegmatites very frequently occur as coarse, central or marginal zones in the veins of aplite and granite, but occasionally thick masses of pegmatite occur without any accompanying granite. In composition the pegmatites vary from a rock fairly rich in biotite to very acid muscovite-pegmatites without biotite. When the pegmatite occurs as a central zone of a granite vein it is usually much more acid than the finer-grained igneous rock, while miarolitic patches have occasionally been seen. All these phenomena are characteristic of newer granite pegmatites.

The distribution of the pegmatites presents some points of interest. Passing westward and north-westward from Gaick and Glen Tromie the biotite-pegmatites and those with accessory muscovite die out, while the coarse muscovite-pegmatites mentioned in the *Summary of Progress* for 1901 (pp. 166–167) increase greatly in number and size in the northern part of Glen Truim and towards the north-west of Dalwhinnie, where their source may be looked for. One statement in last year's report must be corrected, now that these pegmatites have been examined in greater detail; they appear to be intrusions rather than of segregative origin, although the coarseness of grain is probably not due to a very high temperature, and their introduction is of later date than the regional metamorphism of the country.

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In the Gaick area it is noticeable that the pegmatites are more frequent in the lower ground, and decrease perceptibly in number as the hills are ascended. But along certain lines or belts of country there is a marked increase in the number and size of the pegmatites and associated granites. The most notable of these can be traced from a point three-quarters of a mile north-east of Gaick Lodge S.S.E. for a distance of two and a half miles to the Amhainn Gharb Ghaig. At intervals along this line the granite and pegmatite veins become very numerous and large, forming a plexus in which more igneous than sedimentary material is seen. An excellent example of this feature occurs immediately north of the Amhuinn Gharbh Ghaig, about two miles south-east of Gaick Lodge. Mr. Cunningham Craig.

Another increase in the number and size of veins is observed about the lower part of Allt Bhran, in the gorge cut by that stream and for some distance round about it. In this case the belt of country characterised by these intrusions extends in a north-easterly direction, and on Meall an Dubh Catha one mile and a half to the north-east a great development of biotite and biotite-muscovite pegmatites of newer granite type is seen. In this locality the pegmatites may be seen cutting through the quartz veins in the schist, showing that the introduction of the igneous rock took place at a period subsequent to the regional metamorphism. From this locality the pegmatite and granite veins increase in size and number towards the mass of the Cairngorm granite.

The quartz-porphyries are chiefly confined to the higher ground in the Gaick Forest, but in the northern part of the area they descend to the lower ground. They occur as flat-lying sills and attain a thickness of over 100 feet in some places. They are the normal fine-grained porphyries of the newer granite, consisting of idiomorphic phenocrysts of quartz, felspar, and biotite in a microcrystalline or cryptocrystalline base, which sometimes exhibits a beautiful flow structure at the margins.

There are several varieties of dyke rocks of intermediate composition in the area; they are mostly fine in grain, but often have well developed phenocrysts, sometimes of hornblende, sometimes of biotite. Specimens of these rocks have been sent to Dr. Flett for microscopic examination. A fine brick-red felstone, occasionally spherulitic, has also been observed, but is not common.

With regard to the mutual relations of these intrusions some very interesting evidence has been obtained. The quartz porphyries, with some notable exceptions, appear to cut the granites and pegmatites. In the lower part of Allt Bhran and again in the lower part of Allt na Fearna, intrusions of medium-grained biotite granite with pegmatites and aplites have been mapped, and can there be seen passing gradually into the typical quartz-porphyry. In the former case the granite is exposed in the stream section at the bottom of a deep gorge; numerous irregular masses of granite are seen, but none of them reaches high in the section. It appears that merely the top of an under-



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Mr. Cunningham Craig. lying floor of granite is touched in this locality, while the higher ground on either side is characterised by the presence of intrusions of quartz-porphyry. In Allt na Fearna the section is somewhat the same, but not so well exposed. Aplite veins are seen cutting both the granite and quartz-porphyry and the surrounding schist. The exposure of this granite in the low ground is very significant, occurring as it does at a distance of six or seven miles from the main mass of the Cairngorm granite.

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The rocks of the lamprophyre group cut the granites, pegmatites and quartz-porphyries almost invariably; in Coire Bhran, however, a lamprophyre is cut by one of the quartz-porphyry sills.

The granites and aplites are occasionally seen to be intruded into the quartz-reefs occupying lines of fault.

The fine brick-red felstones cut alike granites, pegmatites, quartz-porphyries and lamprophyres. North-east of Gaick Lodge a striking case of this may be seen, where one of the north-east and south-west faults cuts off pegmatite veins and sills of quartz porphyry and lamprophyre, while a dyke of the red felstone has been injected subsequently into the line of fault and occupies it for upwards of half a mile.

From the above evidence it will be seen that the intrusion of igneous material was continued for a considerable time, and that though all the igneous rocks have probably been derived from the same magma, local differences in the rate of differentiation may have caused irregularities in the mutual relations of different groups.

Mr. Hinxman The small area surveyed by Mr. Hinxman, west of Newtonmore, in Sheet 64, is chiefly occupied by the siliceous granulites and coarse flaky muscovite-biotite-gneiss of the Moine series. The relations of these two rock-zones exhibit the usual complex interfolding of the Central Highlands. On the south side of the Spey the general trend of the axes of folding is to the north or north-east, and the dip of the isoclinal folds is to the west and north-west To the north of Glen Banchor there is more variation in the dip, the rocks being thrown into a series of compound synclinal and anticlinal folds.

There seems little doubt that the origin of the granite and pegmatite veins with which the schists of this region are so abundantly permeated, has been found in an intrusion of acid igneous rock which extends from Glen Truim in a north-east direction across the Spey at Cluny Castle to Glen Banchor. Only the eastern margin of this mass has at present been mapped, and it is probable that it has a considerable extension to the west in the direction of Loch Laggan.

The pegmatite veins show an increasing development in the area west of Newtonmore between Glen Truim and the southern slopes of the Monadhliath. They take the form of thin sills or veins of white pegmatite or granite; those showing pegmatitic structures being the most abundant. They are coarsely crystalline to the margin, with no sign of chilled edges.

At the western end of Creag Dubh, above the Laggan Road, these veins increase in frequency, gradually anastomose, and

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finally pass, along a line drawn S.S.W. from Lochan a' Chulaibh to Cluny Castle into the solid mass of white granite and pegmatite referred to above. There is no sharp line of demarcation between the two varieties of rock in this mass, the pegmatitic portions merging into the finer-grained granite. Plumose white mica is a characteristic feature of the pegmatite, and while the fine-grained granite contains a considerable amount of biotite, the predominant mica in both varieties is always muscovite. Mr. Hinxman

Nowhere does this granite show any signs of foliation, but, in common with the veins outside the mass, it contains included fragments, as distinct from isolated portions of the surrounding foliated rocks.

On Binnein Mhor, two miles north of Cluny Castle, the granite is distinctly cut by dykes of red felsite or microgranite, and also by a dyke of coarse quartz-porphyry of the Glen Tromie type. The pegmatite veins external to the mass are also cut by the later lamprophyre dykes.

The field evidence, so far obtained, points therefore to the conclusion that this intrusion is later in origin than the last movements which affected the Moine schists, but earlier than the representatives of what are regarded as some of the latest phases of the newer granite.

With a view to settling the important question of the period of intrusion of these muscovite-biotite-granites and pegmatites, and their relations to the newer or Cairngorm granite, a series of specimens from the Glen Truim and Laggan areas were submitted to Dr. Flett for examination under the microscope.

The general results of his investigations corroborate the field evidence, and are briefly as follows:—

The felspars include plagioclase, orthoclase and microcline, the alkali felspars being most abundant in the more acid pegmatitic portions of the mass. Vermicular micro-pegmatite is sometimes present, and a slight degree of granulitisation, almost entirely confined to the quartz, has been detected in some of the sections. The granitic rocks, though more acid in character than the general type of the Cairngorm granite, are considered by Dr. Flett as probably belonging to the newer granites of the Highlands; while in their mineralogical composition they can be closely paralleled among the granites of the Southern Uplands.

From the Gaick Forest Mr. Barrow continued the re-examination of the ground south to Blair Atholl in Sheet 55. The limit of the granite veins, belonging to the second group in Mr. Barrow's classification (see page 94), was traced, and is now engraved on that map. Mr. Barrow.

Intrusions of newer granite age abound in this southern area, none of which are traversed by the granite veins; but in stream sections the latter are often seen to be cut by the basic members of the newer series. That these veins do not belong to the newer granite is shown by the fact that they die away before reaching the newer granite-complex stretching from Glen Tilt to Glen Feshie.

Some interesting occurrences of biotite-granite have been met with near Blair Castle. They show protoclastic foliation, and thus serve to link the unfoliated biotite-granite veins already

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Mr. Barrow. referred to, and the Ben Vuroch augen-gniess, with its cataclastic structures due to post-consolidation crushing.

Parts of the Tilt Valley and some portions of the Falar area were also re-examined by Mr. Barrow. The point to which attention was principally directed was the original thinning away to the south-east of the colour-banded rocks which have crystallised as Moine gneisses, which pass through a phase of finer sedimentary material, but always retaining their parallel banding. The Little Limestone always occurs on one margin of these rocks, and its occurrence has been noted and traced in the Tilt Valley and in Glen Banvie. On the other side of the parallel banded rocks is the quartzite, from which it may be inferred that the Moine gneisses lie between these these two rocks, viz., the quartzite and the Little Limestone. As the quartzite often passes insensibly into the colour banded series it is equally clear that there can be no erosion-plane on the margin here.

Mr. Cunningham Craig. The revision of the area between Pitlochry and Blair Atholl, in Sheet 55, was completed by Mr. Cunningham Craig, which resulted in bringing to light additional evidence relating to the great intrusion of epidiorite and hornblende-schist of Beinn Vrackie. The intrusion appears to be a large laccolite, and the regularity with which it conforms to the bedding of the surrounding schists is admirably shown by the thin brown limestone at the top of the Beinn Lawers Schist, occurring almost always within a few feet of the lower surface of the igneous rock.

The upper surface of the laccolite is seldom so well exposed as the lower, and over a large part of the area only the lower surface is seen, where it is continually repeated by folding. The junction of the upper surface with the Black Schist is well exposed, however, in several localities. Induration and hornfelsing of the contiguous rock is observed both along the upper and lower margins.

Mr. Wilson. During the spring, Mr. Wilson completed the revision of the area in Strath Tummel and Strath Tay in connection with the publication of Sheet 55. The boundary line between the quartzite and black schist in Strath Tummel was mapped, and additional evidence was obtained regarding the unconformable relation of the quartzite to the adjacent schists.

On the north side of Loch Tummel, Mr. Wilson found a good exposure of Boulder Bed, identical in matrix and included blocks with that so largely developed in the Schichallion complex. As the Strath Tummel bed lies on the east side of the Loch Tay fault, its occurrence there tends to confirm the conclusion that the Schichallion limestone and black schist are the same as those at Blair Atholl.

## PLEISTOCENE.

### *Glacial Phenomena.*

Mr. Barrow. The area surveyed and re-examined by Mr. Barrow includes the whole belt in Perthshire and Inverness-shire, where the great western ice sheet and the local sheet of the east Central Highlands coalesced. It is clear that the western ice accumulated

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more rapidly than that of local origin, and dammed back the the latter, thereby arresting all movement along a certain zone. Within this zone no glacial erosion took place; and hence the Moine-gneisses are now so soft and decomposed that they can be dug readily with the hammer. The limit of advance of the western ice sheet appears to be about 2,900 feet; it may have been thicker than this, but it was unable to force back the local ice at all higher elevations. This point is of importance, because the Ben-y-Ghloe mountains rise to a height of over 3,000 feet and hence may have acted as a pivot to the ice movements. The outer limit of the belt of uneroded ground clings always to the south-west edge of these mountains. As soon as this barrier is passed, the trend of the western sheet becomes more and more easterly, till, as explained on various former occasions, it turns due east, then north-east, and finally, on the Stonehaven coast, almost due north, as noted by Jamieson many years ago.* Mr. Barrow.

In that part of the Gaick Forest examined by Mr. Cunningham Craig, which consists for the most part of a broad plateau rising nearly to 3,000 feet, and cut by deep and narrow valleys, he found that the later glaciation can be readily traced by its lateral and terminal moraines. But the direction of flow of the earlier great ice sheet is more difficult to determine. Ice from the higher and more extensive plateau of the Cairngorm Mountains has apparently never overridden the Gaick plateau, though parts of Glen Feshie were undoubtedly covered by this flow from the E.N.E. No boulders of Cairngorm granite have been observed on the plateau. Mr. Cunningham Craig.

On the other hand, the ice flow moving north-eastward from the Moor of Rannoch and Beinn Alder does not seem to have encroached to any extent upon the western spurs of the Gaick plateau. Boulders of the hornblende granites and diorites from the Moor of Rannoch, though numerous in Glen Truim from Dalnaspidal northward, are rarely if ever observed in the Gaick Forest, except in the low ground about the Tromie. There is some evidence, however, of a movement eastward into Perthshire from the eastern limit of the Gaick Forest and from the plateau between Glen Truim and the Atholl Forest.

From this evidence it appears that the Gaick plateau, though it never reaches 3,000 feet in height, formed part of the ice-shed of the country during the great glaciation. The occurrence of great thicknesses of decomposed rock on the higher parts of the Gaick plateau favours this view. A thickness of 30 to 40 feet of rock, preserving the bedding and granite veins, and so disintegrated that it can be dug out like sand, is not uncommon. Had the surface been intensely glaciated, it is improbable that disintegration could have proceeded to such an extent since the glaciation, and hence this decomposition may be in part pre-glacial.

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* *Quart. Journ. Geol. Soc.*, vol. xxxviii., p. 160.

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Mr. Hinxman

Along the western margin of Sheet 64, Mr. Hinxman observed an important development of the lateral moraines of the Spey glacier on both sides of the valley in the Laggan district; and he also found evidence of a northward movement of the ice over the col from Dalwhinnie in Glen Truim into the Spey valley, and also from the Spey through Strath an Eilich to the head of Glen Banchor.

The lower spurs of the Monadhliath, which separate the three principal tributaries of the River Calder on its north bank, are each cut through, a short distance above the foot of each glen, by a deep and narrow dry gully. The distinct alignment of these gullies, coupled with their common E.N.E. trend and fall to the east, suggests their origin as the line of drainage of a series of small glacial lakes which occupied the upper portions of the valleys of the Allt a' Bhealaich, Allt Fionn-righe, and Allt a' Chaoruinn at a time when Glen Banchor, the valley into which all these glens debouch, was filled with ice.

The upper limits of the shrinking Glen Banchor glacier are well shown by the terraced moraines at the mouth of the Allt a' Chaoruinn glen, and on the hill sides east of Creag an Loin.

Numerous well-rounded erratic blocks of grey hornblende-biotite-granite occur throughout Upper Badenoch and Glen Truim. The source of these boulders may be looked for in the west, in the granite intrusions of the Ben Alder Forest and at the head of the Spey.

A wide stretch of alluvial sand and silt above the constriction of the Spey Valley at Glen Truim Castle indicates the extent of the former lake basin between Auchmore and Laggan Bridge.

The whole of this small area is under sheep, while most of it is grouse moor. Much of the hill ground above the limits of the valley glacier drift is bare and rugged, with shallow peaty soil in the hollows between the rocky eminences. On the west side of Glen Truim there are extensive stretches of drift covered ground, and these, together with the grassy lateral moraines and wide alluvial flats of Glen Banchor and the Spey, afford excellent grazing for sheep and cattle.

Mr. Wilson

During his re-examination of the Tay valley last season, Mr. Wilson obtained evidence pointing to the existence of a glacial lake in the valleys of the Tay and Tummel.

From the northern limit of the narrow "Pass of Birnam," northward to Pitlochry and Grantully, both sides of the Tay and Tummel valleys are occupied by a series of well-marked terraces which lie above the ordinary river alluvium and are almost entirely composed of soft glacial silt and sand with horizontal bedding. From the nature of their contents they could never have been deposited by the present river, but are clearly lake deposits.

For 1¾ miles the whole of the "Pass of Birnam," is filled with a large accumulation of coarse morainic detritus mixed with gravel in the form of hillocks of various size. These rise to 450 feet above sea level, or 286 feet above the solid rock there exposed

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in the bed of the river. This deposit formed the barrier which held back the waters of the lake of Strath Tay and the lower Tummel valley. This sheet of water must have come into existence during the closing phases of the later glaciation. From the thickness of the more or less denuded terraces which remain, the period of time during which this silt was deposited must have been of considerable duration. Mr. Wilson made a number Mr. Wilson.

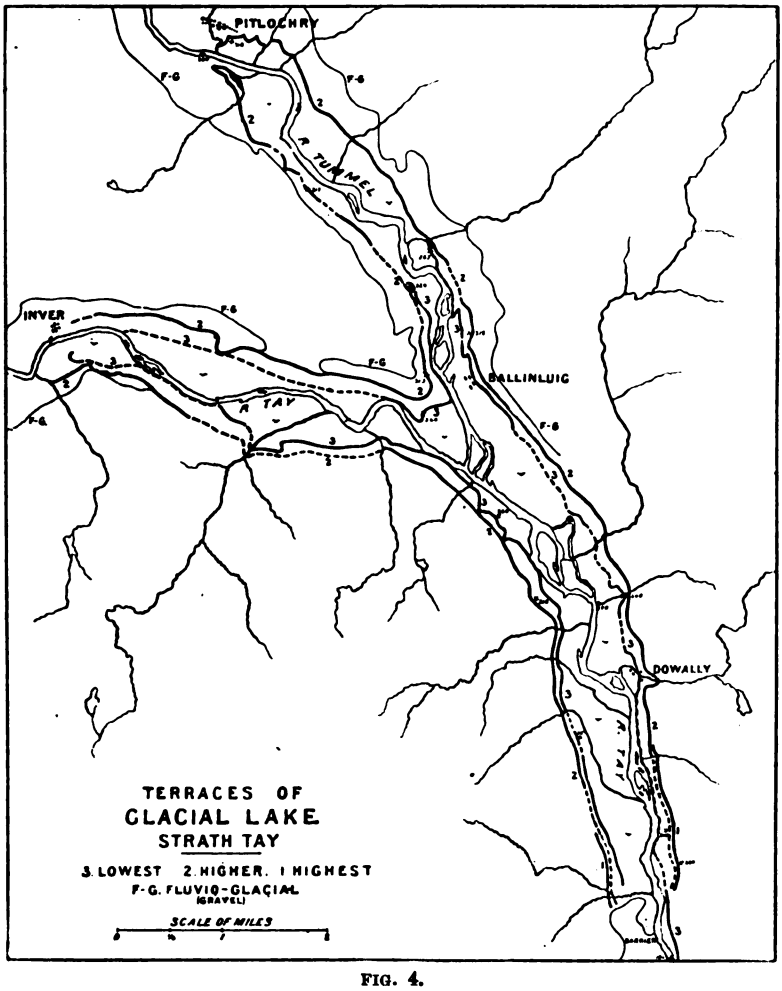


FIG. 4.

of observations with the Abney Level all over these lake terraces and found that, immediately to the north of the barrier at the Pass of Birnam, a terrace, 354 feet above sea level, extends up the Tay valley to Dalguise, a distance of two miles. This terrace at its lower limit ends abruptly on both sides against the moraine barrier. A fall in the level of the lake is indicated by a lower terrace at a height of 316 to 318 feet, which has been traced almost continuously on both sides of the Tay and Tummel valleys to Grantully and Pitlochry. A further fall in the level of the lake

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Mr. Wilson. is recorded by the lowest terrace (269 feet) which has been followed northwards, in the Tummel valley to mid way between Logierait and Pitlochry, and in the Tay valley to near Grantully. During the period which has elapsed since the barrier was finally breached and the lake drained, the Tay has eroded the lower terrace and fragmentary portions only now remain. A careful examination of the sections exposed by the streams which intersect these terraces, together with the numerous levels taken all over them, suggests their lacustrine origin.

Immediately above these lake terraces there is a well marked deposit of fluvio-glacial gravels in the form of hillocks, kames, and sheets. They first appear a little to the south of Ballinluig and extend up both sides of the Tay valley to within a short distance of Aberfeldy, where they merge into the large moraines which stretch from the foot of Farragon Hill and down into the Edradynate valley. In a similiar manner these gravels occupy the Tummel valley and extend to the foot of the large terminal moraines which lie immediately to the north-west of Pitlochry. At several localities they are seen to lie upon the denuded edges of the upper lake terrace, while their upper limit, where not bounded by rock, rests upon stiff Boulder Clay.

The position occupied by these gravels, together with the general character of their materials, seems to indicate that during the period when the lake was gradually shrinking by the lowering of its barrier there was a temporary advance of the western and northern ice.

A very important fact in economic geology relating to the future water supply of this district is that the upper limit of these gravels is very clearly defined by a series of strong springs of good, potable water, particularly between Edradour and Delcapon in the Tummel valley.

## 4.—Rum, Eigg, and Part of Mull.

Dr. B. N. Peach, F.R.S., District Geologist.
Mr. George Barrow, Mr. Alfred Harker, F.R.S. } Geologists.

The geological formations and groups of rock entering into this district, are as follows, in descending order:—

vi. Post Glacial and Recent.
v. Glacial Deposits.
iv. Tertiary, chiefly Volcanic and Intrusive Igneous Rocks.
iii. Jurassic.
ii. Cambrian (detached masses in lines of crush).
i. Torridonian.

### Isle of Rum.

Mr. Harker. The mapping of the Isle of Rum was begun during the past year by Mr. Harker, and engaged him through the field season. The total area of the island is about forty-two square miles and three-fourths of this has been completed. Excepting a small farm at Kinloch and a few isolated crofts in other places, there is no cultivation; the island being devoted partly to sheep, but

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chiefly to deer. It divides roughly into a northern moorland tract, of which the highest points fall a little short of 1,000 feet, and a southern mountain tract with much more pronounced relief. Although the greatest altitude of this is only 2,659 feet, some of the peaks have bold outlines, and they are in general of naked rock. Mr. Harker.

### TORRIDONIAN AND CRUSHED CAMBRIAN STRATA.

Torridonian strata make the country rock over the northern part of the island, and extend as a strip along the east coast. The relatively undisturbed portion of the formation, which covers the greater part of this area, has a general dip to W.N.W. at angles usually between 10° and 20°. It divides into two groups; the upper of felspathic sandstones with a more or less pronounced reddish colour, the lower principally of dark shales. The apparent thicknesses of these two groups, as observed, are about 9,000 feet and 1,400 feet respectively; but widespread signs of disturbance on a small scale forbid us to attach any precise value to these estimates. Close observation reveals numerous violent contortions in the sandstones and acute zigzag folds in the shales, where on a cursory view the appearance is that of a steady gentle inclination. Owing to the arrangement described, the upper or sandstone group occupies the greater part of the Torridonian area, the shales below occurring especially on the east side.

Disturbances on a larger scale and with more striking results are seen in two districts. The first is a small area in the north-western part of the island, named Monadh Dubh. Here a considerable overthrust fault, with a gentle inclination to N.W. has brought a cake of highly disturbed rocks, about one mile by two-thirds of a mile in extent, to rest on the ordinary sandstones. These latter show to the eye no special sign of disturbance. Immediately above the thrust-plane comes in most places a crush-band consisting largely of limestone, mingled with sandstone. The two rocks are brecciated and in part ground down together, but there are lenticles of limestone several yards in length. It is easily recognised as the Cambrian (Durness) Limestone, a rock which has not been found in place on the island. To this calcareous band, which is not many feet in thickness and not everywhere continuous, succeeds a greater thickness of crush-breccia or crush-conglomerate composed of red sandstone with only occasional lenticles of limestone. This passes up into a schistose rock, which seems to be essentially a mylonite of sandstone, but still contains a few pieces of limestone. The isolated occurrence of this patch of overthrust rocks, cut off to the north-west by the sea, precludes any further direct examination of their relations.

The second district of highly disturbed strata is more extensive. It is in the east-central, eastern, and south-eastern parts of the island, and consists of a belt of overthrust Torridonian bordering the mountain tract along this line. The mountains are built of Tertiary plutonic rocks, intruded not far from the overthrust—in this place a little above it. Farther

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Mr. Harker. west the prolongation of the overthrust is lost, owing to the encroachment northward of the intrusive rocks. The thrust-surface itself is curved, and its inclination varies considerably. In the central part of the island the effect of the movement—neglecting minor overthrusts in advance of the main one—has been to bring the lower group (shales) to overlie the upper (sandstones). A prominent feature is the prevalence of crush-breccias, sometimes attaining a considerable thickness. Both sandstone and shale have contributed to these; and much of the breccia has probably been furnished by the transitional strata, which are alternations of sandstone and shale. In the strip of overthrust strata bordering the east coast, the relations are sometimes more complicated, and the disturbance seems to be more intense. This is especially the case on the slopes of Beinn nan Stac and Sgùrr nan Gillean. Along the whole of the belt the disturbed strata have suffered metamorphism, sometimes of a high degree, in consequence of the large Tertiary intrusions. A feature of special interest is the occurrence of lenticular masses and patches of gneiss, usually of acid composition, but partly also basic and of mingled (hybrid) nature. These are undoubtedly intruded in the Torridonian rocks, which are always highly metamorphosed at these localities; and various facts which cannot be detailed in this place, suggest that the gneisses belong to the Tertiary intrusions of the district. Their injection is clearly posterior to the great disturbances; but, exceptionally, the gneisses themselves have been crushed and brecciated, indicating (on the hypothesis suggested) a certain amount of movement in Tertiary times along the old lines.*

## Isle of Eigg.

Mr. Barrow. During last season Mr. Barrow began the mapping of the Island of Eigg, which is made up partly of Jurassic sediments and partly of volcanic and intrusive igneous rocks of Tertiary age.

### JURASSIC.

*Northern Part.*—The northern part of the Island of Eigg presents an unusual structure. Though built up of beds which are approximately horizontal, more than half of these are sheets of igneous rock.

Dealing first with the sedimentary rocks, the youngest are of Oxfordian age, and the oldest met with during last season belong to the Great Estuarine series, locally representing the Great Oolite.

*The Great Estuarine Series. (Great Oolite.)*

(1) The lowest beds met with consist of dark shales containing comminuted shell limestones. These are so much split up with numerous intrusions of basaltic rock that it is impossible to

* See Harker "The Overthrust Torridonian Rocks of the Isle of Rum, and the Associated Gneisses." *Quart. Journ. Geol. Soc.*, 1903

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ascertain definitely their thickness, which, however, must exceed a hundred feet. The basement beds of this group contain fish scales, and are probably on the same horizon as similar shales in Skye. They certainly overlie the Inferior Oolite. Mr. Barrow.

(2) The shales just referred to are overlaid by the Great Estuarine Sandstone which probably attains a thickness of some 200 feet, and is divided into three or four portions by partings of muddy sediment, which are thin and not always persistent. Comminuted shell bands also occur but are rare, and plant remains are fairly common near the base. The sandstone has long been famous for its huge concretions. The well-known musical sands noted by Hugh Miller are derived from the disintegration of this rock. The Great Estuarine Sandstone passes up into a limestone, from 10 to 12 feet thick, divided by a shaly parting containing layers of the well-known fibrous calcite. The comminuted shell bands in this series clearly represent the *Cyrena* Limestone of Skye.

(3) The limestone, overlying the Great Estuarine Sandstone, is succeeded by about 10 feet of shale, in turn overlaid by a calcareous grit which passes up into a cream coloured limestone, the whole being about 20 feet thick. Fossils are scarce except at the base of the grit, which latter presents many of the characters of beds that contain derivative forms, and care must be taken to make certain that the fossils belong strictly to this bed. In the higher calcareous bands in the shales the fossils that do occur are often comminuted, but there can be no doubt that they represent the *Paludina* Limestones of the Skye succession as worked out by Mr. Wedd. At the base of these shales the typical *Ostrea hebridica* beds occur, which seem to form a singularly persistent horizon in the Oolitic rocks of the Western Isles of Scotland. They are exposed in the little gorge east of Laig farm. Close to the Catholic Chapel, the lowest *Ostrea* Limestone has been quarried.

Above the cream-coloured limestone a gap appears in the sequence owing to igneous intrusions, and to the section being hidden by sand at Laig Farm.

#### OXFORDIAN.

On the other side of the gap, and on the south shore of Laig Bay there occurs a set of soft grey shales containing cordate Ammonites of undoubted Upper Oxford Clay age. These rocks are the youngest of the Jurassic succession met with in this region during last season.

### Isle of Rum.

#### TERTIARY VOLCANIC, AND INTRUSIVE, IGNEOUS ROCKS.

Of the Tertiary igneous rocks, which occupy fully one half of the area of Rum, by far the greater part occur in the form of massive intrusions referable to the plutonic phase of activity. The preceding volcanic phase is represented in the western portion of the island by some patches of basaltic lavas, etc., Mr. Harker.

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Mr. Harker. partly resting on the Torridon Sandstone, and partly enveloped in granite. Elsewhere these lavas, which have doubtless had a very wide extension, have been stripped away in the progress of denudation. The final or "dyke phase" is represented by basic dykes and sheets, which traverse the plutonic rocks as well as the Torridonian strata; but, though these minor intrusions are numerous, their total bulk is insignificant in comparison with the large masses.

The plutonic rocks, which build the mountains of Rum and form also some of the lower hills, belong to three great groups—ultrabasic, basic, and acid. These were intruded in order as named, *i.e.*, in an order of decreasing basicity, and the three groups are fairly comparable as regards the scale on which they are developed. They correspond in the order of their intrusion, as they do generally in their petrographical characters, with the three groups of plutonic rocks distinguished in the central mountain district of Skye; but there are noticeable differences between the two areas. In particular, the ultrabasic group attains in Rum a much greater prominence than in the more northerly island, and presents an interesting variety of petrographical types. This is certainly the most distinctive feature of this special focus of igneous activity.

The ultrabasic rocks build a large part of the Rum mountains, including Askival, Allival, and Barkeval, and further form a tract of lower hills in the west-central part of the island. The area thus indicated is continuous, with a greatest extent of about 4½ miles. In addition, there are numerous small intrusions in the Torridonian tract to the north and north-west. Petrographically, the rocks present a considerable range of variety, especially in the large continuous area, which must be a complex formed by numerous injections. Olivine is usually a very abundant constituent, and ordinary varieties of peridotites and picrites generally prevail, at least on the lower ground. In Allival and Askival, however, these are associated with more felspathic types, the felspar being constantly anorthite. There are simple olivine-anorthite rocks, and others in which the pyroxenes, augite and enstatite, enter in various proportions. The several types alternate in parallel sheets, with a gentle inclination to the horizon; in addition to which there may be some banding on a smaller scale, and in places a parallel disposition of the component crystals. In other types, again, a rhombic pyroxene partly or wholly takes the place of olivine, giving a very beautiful enstatite-anorthite rock, a pure enstatite-rock, and other varieties in which augite and olivine also take part. A considerable area of rocks of these kinds occupies the hills to the north of Harris and near Loch an Dornabac, and here they are seen to break through the peridotites, giving rise along the junction to a broad zone of intrusion-breccia.

The gabbros which constitute the second group of plutonic intrusions, are probably in great force in the southerly mountains, which have not yet been surveyed. On the ground mapped during the past season those rocks occur chiefly as a massive

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irregular sheet or laccolite (probably continuous with the main body), intruded at the base of the preceding group along the north-easterly and easterly slopes of the mountain tract. There is less petrographical variety than in the ultrabasic group, and the banding, though often evident, is less pronounced. The posteriority of the gabbro is clearly shown in many places. In addition to the principal area, there are numerous smaller masses breaking through the ultrabasic rocks and the Torridonian strata. Mr. Harker.

The third (acid) group of plutonic rocks is developed especially in the western part of Rum, where Orval and the neighbouring hills are formed by a large mass of granite. The rock is usually hornblendic, the hornblende being in part derivative after augite, and, like other British Tertiary granites, it has a strong tendency to micrographic structures. The acid gneisses of the island, which we have proposed to assign to the Tertiary suite of intrusions, present very similar characters, and on Beinn a' Bhàrr-shaibh there is a patch of gneiss, about a quarter mile long, enclosed in the granite with no sharp line of demarcation.

Intruded in the belt of overthrust Torridonian, and below the gabbro, there occurs in several places a conspicuously porphyritic quartz-felsite, with fine-textured dark ground-mass and constant flow-structure. On Meall Breac and elsewhere it is often crowded with *débris* of other rocks, especially of gabbro, from blocks many feet in length down to microscopic fragments. The felsite seems to be of later intrusion than the granite, but its precise position in the suite of associated rocks remains to be determined.

The minor intrusions in the form of dykes and sheets are of later date than the plutonic rocks, and they are all of basic composition. A number of strong sills intercalated in the basaltic lavas of Fionn Chrò belong doubtless to the group so largely developed in Skye and elsewhere. Basalt dykes of small or moderate dimensions intersect the plutonic rocks of the mountain tract, but are much more numerous in the Torridonian area. In their varying direction they show a very decided tendency to a radiate arrangement with reference to the mountain centre, *i.e.*, the south-central part of the island. Thus the prevalent bearing in the north-western area is N.N.W., in the north-central N., in the north-eastern N.N.E. As we pass southward in the eastern part of the island, the bearing changes to E.N.E., E., E.S.E., and S.E. To this radiate disposition there are many exceptions, and the types doubtless belong to more than one group, intruded at different epochs. In many places there are dykes running at right angles to the dominant radial set. In addition to the dykes, there are in the Torridonian tract numerous sheet-formed intrusions, either following more or less closely the bedding of the strata or curving irregularly and rapidly swelling out and tapering away. A prominent example occurs near Kilmory. Some of these sheets are perhaps to be correlated with the more regular sills in the lava group, but others are of later date, and intersect the basalt dykes,

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## Island of Eigg.

### TERTIARY VOLCANIC ROCKS.

Mr. Barrow. The igneous rocks of Tertiary age are divided into two groups by the Great Estuarine Sandstone. The upper group consists of a mass of decomposed basic igneous rock built up of continuous sheets with no visible ash or sedimentary material between them. Whether these sheets are sills as maintained by Hay Cunningham or true lava flows actually poured out at the surface, has not been proved by the evidence in the northern part of the island. At the base of the sheets are two specially interesting rocks. The lower is an olivine-dolerite, often 100 feet in thickness and rarely columnar in the northern portion of this area but usually so further south. Its base in the gorge east of Laig Farm is well exposed where its intrusive nature is clearly seen. The higher band is described by Mr. Harker as a mugearite and formerly by Sir A. Geikie as anamesite. A peculiar feature of the mugearite is its more or less persistent vesicular character. Moreover, the cavities are almost always elongated, are empty and have sharply defined walls. Now the olivine-dolerite below displays in a very perfect form the red top that is so often claimed as evidence of a land surface, but as the rock is intrusive this feature must be due to some other cause. The evidence on the ground makes it clear that the overlying intrusion, which is often crowded with gas cavities, acted as a local fumarole, and the red band is probably due to local fumarole action. Each successive intrusion seems to have introduced corrosive gases into the rocks, and it is an invariable rule that the oldest sheets are the most decomposed.

The lower group are evidently intrusive. The lowest member is a sill, more than 50 feet thick, composed of markedly basic material. Higher up is a markedly acid rock containing phenocrysts of quartz, which in one place reaches a thickness of at least 100 feet. It forms the foot of the cliff at the extreme north of the island, where it displays a well marked columnar structure.

The shales in their upper part are pierced by a number of thin dark sills, rarely more than ten feet thick, composed of olivine dolerite and often possessing columnar structure.

The closing phase of volcanic activity is marked by a great number of narrow dykes, which in some places give rise to small sills; an excellent example of which occurs in the mass of quartz-porphyry at the north end of the island. The dykes are fresh and as a rule fine in grain, though occasionally a small dyke is met with containing visible crystals of olivine, augite and felspar. These dykes always occur in small cracks which can often be proved to be lines of fault. As we approach one of these, the amygdules in the basic sheets, usually filled with calcite, invariably increase both in size and number. It is quite clear, therefore, that these amygdules cannot be taken as conclusive evidence that the rock was originally vesicular, still less that it was a lava flow.

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## MULL.

In order to complete sheet 36, it was necessary to map a small portion of the south coast of Mull, including the headland named Malcolm's Point, to the west of Carsaig Bay. This was done by Mr. Harker. The cliffs here belong to the Tertiary basaltic group, and to the lower portion of it, the Cretaceous sandstones emerging from below sea-level only a little to the east, towards Carsaig. The basaltic lavas are mostly amygdaloidal and not of a very durable nature, but at numerous horizons are intercalated strong intrusive sills of dolerite. These become more numerous towards the upper part of the section, where the cliffs become accordingly more precipitous. Interposed among the basalts, near the base of the group, is a basaltic tuff, associated with which, and passing into it, is a conglomerate of rounded flint pebbles. This conglomerate, with a maximum thickness of about fifteen feet, is of quite local occurrence, and is doubtless a river gravel belonging to an early epoch in the volcanic period. Mr. Harker.

## ISLE OF RUM.

### PLEISTOCENE.

#### *Glacial.*

The glacial geology of Rum has been only very partially worked out, and the evidence seems to be not very complete. The fact that foreign boulders are found up to high altitudes, though sparingly and in diminishing numbers, may be taken to imply that the whole island was probably over-ridden by the Scottish ice-sheet. But though the ground reaches no lofty eminence, the relief is, at least in the southern half, of a bold type; and the trend of the striae shews that the movement of the ice was partly controlled by the more marked features of the land surface. On the more open ground the direction was towards W. N. W. There are abundant signs of a minor local glaciation succeeding the principal invasion. Thus, along the south side of Kinloch Glen, the main set of striae, directed westward, is crossed by a second set, pointing northward, i.e., from the principal high ground. In some other places indications of movement down a valley may point to glaciers of late date; but it is not always possible to discriminate the two sets of striae.

Drift accumulations do not in general attain any great development in Rum. Continuous deposits are usually almost confined to the floors of the main valleys. In Glen Harris and Glen Duibhal, however, on the west side of the island the drift is in greater force, and reaches a notable thickness.

## ISLAND OF EIGG.

*Glacial.*—A number of boulders clearly derived from the mainland occur on the north and north-east shores of Eigg, but so far no typical boulder clay has been met with. Erratics are locally abundant on the higher ground in the central part of the Mr. Barrow.



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Mr. Barrow island and often occur in lines; each composed of one kind of rock, either quartzose Moine-gneiss or pegmatite. The ice streamed over the high cliffs of Cleadale, carrying boulders of pegmatite with it and eroding shallow hollows, which have been proved by draining to be true rock-basins.

## Isle of Rum.

### POST GLACIAL AND RECENT.

Mr. Harker. Although the rivers of Rum are necessarily of small volume, there are considerable gravel flats in the glens of Kilmory and Kinloch. Raised beaches are found on the sheltered parts of the coast. A twenty-feet beach makes some spread at Kilmory (where there is a well-preserved raised bar) and other places, while higher beaches occur at Harris and, in a fragmentary state, elsewhere. The peat, which covers much of the moorland ground, does not attain any considerable thickness.

It is worthy of note that during recent years the drainage system of the island has been artificially modified, as part of a scheme for improving the fishing in the Kinloch River. A portion of the drainage from neighbouring valleys has been diverted into Kinloch Glen. This work, begun and abandoned many years ago by the late Marquis of Salisbury, has now been carried out by the present proprietor, Sir George Bullough. It results that the Kilmory River, robbed of a part of its water, is no longer in proportion to its valley and to the gravel flat through which it meanders; while the volume of the Kinloch River is notably augmented. It will be of interest in the future to note the process, already perceptible in places, of adaptation to the changed conditions.

## Island of Eigg.

### RECENT.

Mr. Barrow. The movements that have taken place in Eigg in comparatively recent times are well shown by the phenomena associated with the alluvial flat about Laig Farm which marks the site of an old lake.

The sequence of events is briefly as follows:—

1. The island stood at a much higher level, during which period a deep valley was eroded by the two streams that now flow down into Laig Bay. The valley was carved out of the sedimentary material and extended far into the area now covered by the sea.

2. The land sank some hundreds of feet and the two streams discharged their sediment into the old valley; the sand being derived from the speckled black and white detritus of the olivine dolerite sheets.

3. The ice that streamed across Eigg dug out this incoherent material under the inland cliff, heaping it up close to the sea. The land at this period must have been about 100 feet below its present level, for there is clear evidence of the 100 feet beach on the west side of Cleadale.

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4. The land subsequently rose and a fresh water lake was formed owing to the bar of heaped up material already mentioned; the latter being slowly cut through by the two streams till eventually the lake was drained. Mr. Barrow.

A curious confirmation of the fact that a valley was cut in the softer rock far beyond the present limits of Eigg is afforded by the fact that this filled up valley has been selected as the only part of the sea floor where the telegraph cables would be safe from injury during storms. They repose far out to sea on the sand filling the old valley.

ECONOMICS.

As the rainfall in Eigg is less than that in Skye the soil is not nearly so much washed away, and the upland forms rich grazing ground owing to the fertility of the material produced by the decomposition of the dolerite. The Cleadale and Kildonan areas are cultivated by the crofters where the land is comparatively flat and fertile. A practically inexhaustible supply of road metal exists in the island, but as there is no harbour, it is not available for economic purposes on the mainland.

Peat grows on certain flat, almost water-logged, surfaces and is of excellent quality. There seems a sufficient supply to last for some years.

5. REVISION OF CABONIFEROUS AREAS:

A.—MIDLOTHIAN, PART OF WEST AND EAST LOTHIAN AND PEEBLES-SHIRE.

Dr. B. N. Peach, F.R.S.—District Geologist.

Mr. L. W. Hinxman, B.A.
Mr. J. S. Grant Wilson
Mr. E. H. Cunningham Craig, B.A. } Geologists.

When the Lothians were first mapped by the Geological Survey, the oil shales were not known to be of commercial value. After the development of the field was begun, the revision of the area was undertaken, first by Sir A. Geikie, and subsequently by Mr. H. M. Cadell, who, during his connection with the Survey, re-mapped the whole oil-shale field west of Edinburgh, and, since his resignation, has kindly kept the information on the six-inch sheets up to date. In the course of his revision, Mr. Wilson has confirmed the conclusions arrived at by Mr. Cadell regarding the structure of the oil shale field. Mr. Wilson.

The greatest addition to our present knowledge was supplied by bores recently put down in the area lying between Broxburn, Pumpherston, and the River Almond, whereby the outcrops have been traced, of the Dunnet, the Pumpherston, and the Barracks oil shales and the Burdiehouse Limestone throughout this hitherto little known district.



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Mr. Wilson. Some doubt still remains as to the exact horizon of an oil shale supposed to be the Dunnet in the Philipston and Linlithgow Fields. Mr. Wilson is of opinion that it is not the Dunnet shale, but an oil shale locally known as the "grey shale," that lies between the Broxburn and Dunnet seams.

It has been observed that in this region all the shales, with very few exceptions, deteriorate both in the quantity and quality of their oil-yield as they are followed downwards. Mr. Wilson has obtained the following evidence, which seems to favour the opinion that this deterioration is in some manner due to the depth of the seams below the surface.

In No. 1 mine, Philipston, which is sunk in the Broxburn seam, the shale, from its outcrop down to 30 fathoms vertical depth, gave a yield of 25 to 26 gallons of crude oil per ton. From this point downwards the return gradually became less, till, at a depth of 70 fathoms, it had fallen to 11·3 gallons per ton. The lithological character of the shale likewise changed; it became more dense, lighter in colour, and more distinctly ribbed.

At No. 5 mine, in the same field, the Broxburn shale at its outcrop yielded 30 gallons per ton, 25 gallons at 100 fathoms, and then its yield rapidly fell till, at 150 fathoms, it amounted to 12 gallons of crude oil per ton. In this mine the bottom leaf of the seam wrought is a strong, "curly" shale, and continues to be so down to 100 fathoms. At this depth, and coincident with its decreasing yield of oil, it gradually becomes so much broken up that it practically passes into what coal miners call "dross" that would pass through the meshes of an inch and a-half sieve. These small pieces are thinly coated with a black, lustrous substance, which, on analysis, proves to be albertite. A large mass of this mineral was lately found in the shale in this mine.

The above question has also been investigated by Mr. George F. McKillop, chemist to the Broxburn Oil Company, and he finds that any oil shale, as it increases in depth, deteriorates both in its yield of oil and in the quality of the oil produced. The denser and deeper shales have less hydrogen and also less carbon, and the result of this deficiency in hydrogen is that the shales, on distillation, have a tendency to form denser carbon compounds of the "olefine" and "acetylene" series, and also compounds of the "napthalene" and "benzene" series. The crude oil is also specifically heavier than that obtained from the same seam at higher levels. The crude oil, on the first distillation of the dense shales to dryness, leaves a much larger deposit of carbon than the oil from a higher level. From the consideration of these facts it would appear that, in the basins into which those shales have been thrown by plication and faulting, now separated by denudation, there has been a slow process of distillation going on, whereby the higher parts of the seams have been enriched at the expense of their more deep-lying portions. Another important fact also leading to this inference is that, no matter how the yield of crude oil varies in the different parts of any shale, the amount of ammonia remains constant.

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Mr. Wilson mapped out a band of massive limestone in the area south of Linlithgow that probably represents the lowest of the Abden limestones in Fife and one of the Longcraig group of the Dunbar shore. Mr. Wilson.

## PLEISTOCENE.

### *Glacial and Post Glacial.*

Mr. Wilson found that the boundary lines for the Boulder Clay and glacial gravels require only slight modification; he mapped considerable areas of peat and alluvium, including the glacial lake of Winchburgh, the boundaries of which had not been defined, and he further traced the limits of the 100 feet and the 50 feet raised beaches.

## ECONOMIC GEOLOGY AND WATER SUPPLY.

*Brick-making.*—The brick-fields at Blackness and Lampinsdub have been abandoned on account of the lack of railway communication. These are now replaced by three large brick works at Winchburgh, Camps and Ecclesmachan equipped with the most modern machinery and continuous burning Hoffman kilns. The material used at the first two localities is Boulder Clay and "blaes" which are excavated together in about equal proportions. The large stones in the clay are thrown aside and the mixed material is ground in a pug mill and then passed through brick-making machines. At Camps the output per day averages 20,000 bricks. The material used at the works at Ecclesmachan, which are now idle, was Boulder Clay and the black shale on top of the Binny sandstone. At Camps the shale lies immediately above the Burdiehouse limestone and at Winchburgh the fakey blaes (sandy shale) is in close proximity to the Dunnet shale. The bricks produced at both works are of good quality.

*Freestone.*—The extensive quarries at Ecclesmachan in the Binny sandstone are now abandoned, but a large quarry has been opened in the same bed of rock to the north-east of Winchburgh on the Forth Bridge Railway which produced excellent building material. Another equally good quarry is situated at Pardovan, probably on the Kingscavil sandstone, the horizon of which is a little above the "two feet" coal.

*Water Supply.*—The water supply all over this part of the country is very deficient. The streams as the result of the oil and mining industry are all more or less polluted. That the Calciferous Sandstone series as here developed does not hold much water is proved by the small amount of pumping required at most of the oil-shale pits and mines. Very few wells are now used and the district is almost entirely served by water mains which draw their supply from the hills to the south, outside the present area.

Mr. Wilson wishes to take this opportunity of thanking the mining engineers at the different shale works visited by him, who have kindly placed their entire information at his disposal. He has examined a large number of mining plans and procured

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Mr. Wilson. copies of numerous vertical and horizontal sections and also of the journals of several important bores made with the diamond drill.

Mr. Hinxman. Mr. Hinxman examined the Carboniferous Limestone area that occupies the south and south-eastern part of the Midlothian Basin between Gorebridge, Howgate, and Penicuick.

Owing to the thick covering of drift over most of this ground, it has not been found possible to separate the limestones of the lower group throughout the area. At certain points where new evidence is available, as between Middleton and Esperston, the lines on the present map have been slightly modified, and to the south of Mount Lothian the limestones have been differentiated for a short distance.

There is evidence that the limestones become much thicker in the southern part of the area, and as this may be due to the coming together of two or more bands and consequent elimination of the intervening strata, it does not appear advisable to draw, what must be purely conjectural lines, for the outcrop of the bands through drift covered country. It is perhaps safer to indicate by one colour the belt occupied by the lower group of limestones as a whole, separating the different bands where they can be traced by a deeper shade of the same. Most of the quarries in the district are now closed, and the limestone is now only wrought at Middleton and Esperston limeworks, the former in No. 1, the latter in Nos. 2 and 3 limestones. The stone is of good quality and is used entirely for building and agricultural purposes.

Plant-remains have been collected by Mr. Tait from the shales and sandstones that immediately overlie the highest (No. 6) Limestone to the N.E. of Penicuick. These have been submitted to Mr. Kidston who has identified among them, Lower Carboniferous species of *Lepidodendron* and *Astero-calamites;* and also a *Sphenopteris* of Lower Carboniferous type. He considers the fossil evidence conclusive as to the Lower Carboniferous age of the strata containg these plant remains.

In the North Esk River at Esk Mill, and in the burns which fall into the Esk at Auchindinny House, the sections show that the upper limestone is succeeded by 120 to 150 feet of dark shales with ironstone nodules and faky sandstone, from which the plant remains referred to above were obtained. Above these come a series of thick bedded, yellow, grey, and reddish gritty sandstones with occasional intercalations of shale. From one of these intercalated bands of dark shale with ironstone nodules, quarter of a mile east of Auchindinny, Mr. Tait has obtained *Calamites* of Lower Carboniferous type.

*Drift.*—A wide sheet of sand and gravel covers most of the lower ground that extends northwards from the base of the Moorfoot Hills. The gravel seems everywhere to be underlain by Boulder Clay which is exposed by denudation in the valleys and stream sections. The plateaux-like character of the deposit

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is well marked between Gorebridge and Borthwick where the flat summits of the undulating plain rise to a uniform height of between 700 and 800 feet. Mr. Hinxman.

In the western district, between Penicuick and Temple, the gravels are more irregularly arranged, and often form isolated mounds and kamiform ridges. An examination of the gravel points to its having been derived from the west. A large proportion of the pebbles is composed of volcanic and basic igneous rocks, similar to those of the Pentland Hills and the country to the west of that range.

*The Pentland and Braid Hills District.*—During the revision of Sheet 32, a large part of the Pentland Hills has been re-examined. In this area the structure has been found remarkably difficult to elucidate. As is well known, a series of conglomerates and sandstones of Lower Old Red Sandstone age rest on upturned Silurian strata, which are succeeded by lava flows of basic andesite, felsite, and andesite of less basic composition, while intercalations of ashes, conglomerate, and sandstone occur here and there. It has also been pointed out that the lowest conglomerates are formed of greywacke, radiolarian chert, and acid igneous rocks of earlier date, while at higher horizons, even before the first volcanic rocks are reached, pebbles of andesite appear. It is now found that the lowest conglomerate is repeated more than once amidst what was formerly believed to be a regular upward succession from north-west to south-east. The mapping of faults which repeat the succession or part of it has entailed the careful re-survey of much of the ground. Mr. Cunningham Craig.

Of the volcanic necks represented on the map, it is found that only one or two small ones can be proved to be actual vents, the larger ones, such as those on Torduff Hill and the Braid Hills, consist almost entirely of lava flows chiefly acid in composition.

The area is not yet fully examined, and many parts of the structure may remain obscure owing to the paucity of exposures and the lack of clear sections.

*Arthur's Seat and the City of Edinburgh.*—The chief point of interest in the revision of Arthur's Seat is the discovery of a mass of agglomerate extending from near the "Cat Nick" on Salisbury Crags almost to the old "Camstone Quarry" on the south side of the Hunter's Bog. This mass probably represents an independent volcanic vent or neck from that which forms the "Lion's Head" and the "Lion's Haunch." The agglomerate is made up chiefly of blocks of olivine-basalt set in a finer matrix of the same material, together with a certain amount of sand. The matrix has been much hardened, suggesting the idea that it has been altered by the intrusion of the sheet of dolerite of Salisbury Crags. An attempt has been made to map out in detail the material that now fills the larger vent forming the main mass of Arthur's Seat, which, as is well-known, is partly made up of agglomerate, lavas, and various intrusive rocks. Dr. Peach.

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## B.—Prestonpans to Cockburnspath.

Mr. C. T. Clough, M.A., District Geologist.

Mr. G. Barrow
Dr. C. B. Crampton } Geologists.
Mr. E. B. Bailey, B.A.

The revision of the Carboniferous Rocks in one-inch Sheets 33 and 34, was begun last autumn. These belong partly to the Calciferous Sandstone series and partly to that portion of the Carboniferous Limestone series of Scotland * which comes below the Edge Coals of Mid Lothian. To elucidate the geological structure it was found necessary to examine some portions of the Upper Old Red Sandstone.

Most of the district is deeply covered with superficial deposits which greatly obscure the solid geology.

Mr. Clough. The narrow tract of Carboniferous rocks between Oldhamstocks and the eastern outskirts of Dunbar is bordered on the west by a great line of disturbance, generally striking N.N.W., and the strata near this line are also almost parallel to it and inclined at high angles. In Ogle Burn and Broadwood Burn, we find, mixed with the coarse Old Red Sandstone conglomerate on the west side of the line, thin strips of Silurian greywacke and shale, striking N.N.W., almost at right angles to the usual strike in the Lammermuirs. Near Broxmouth, the disturbance is represented by several lines of fracture and contortion. The beds are frequently reversed, and the sandstones and shales below the Skateraw middle limestone are thrown into small folds, some with both limbs inclining W., and crossed by several small thrusts dipping W. at low angles. On the shore N.N.W. of Broxmouth, the beds belonging to the Carboniferous Limestone series, the Cementstone division, and the Upper Old Red Sandstone, are generally reversed, with a steep westerly inclination, and, some distance west of the most disturbed part, the Old Red Sandstone is twisted into a sharp double fold in which the axial planes strike nearly N. and S., and the western limb of the anticline is steeper than the eastern.

These phenomena near Broxmouth indicate that in this locality the beds west of some of the lines of fracture, have been to some extent thrust over the higher beds on the east.

It may also be said that on the coast east of Skateraw and nearly a mile and a half E.N.E. of the line of disturbance referred to, the Skateraw middle limestone is often folded into small anticlines and synclines, with axial planes striking about N.N.W. and generally either vertical or inclining west. In one place, also, a little thrust is seen, dipping west at about 20°.

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* Mr. Gunn has shown ("Correlation of the Carboniferous Rocks of England and Scotland," *Geol. Mag.* 1898, Dec. iv. vol. v. p. 342) that the Carboniferous Limestone series of the North of England includes many beds which are below the Carboniferous Limestone series of Scotland.

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## CALCIFEROUS SANDSTONE SERIES.

*Dunbar and Cockburnspath District.* — At Cove harbour, Linkhead, Thornton, and in Dunglass dean there are thin impure crinoidal marine limestones which must be far below the line which has been taken as the base of the Carboniferous Limestone series of Scotland. There are two limestones at Cove harbour, and it seems probable, on stratigraphical grounds, that the lower of these is on the horizon of the Linkhead limestone, but they differ from each other in their fossil contents. Mr. Clough.

A little below the lower of the two limestones at Cove comes the massive, yellow or red, sandstone of Heathery Heugh with some thin partings of purple or pale grey clay; the thickness being about 160 feet. Below this comes a series of dark grey shales, thin sandstones, fireclays and thin coals (Scremerston division), none of the latter being more than ten or eleven inches thick. These coal-bearing beds are all nearly vertical, being near the north side of a large fault,—not noticed in the original survey,—which on its south side has beds belonging to the Cementstone division. On the foreshore west of, and overlying, the Upper Old Red Sandstone, there are shales and cementstones, from 50 to 60 feet thick, followed by a fine-grained, pale grey sandstone, about 150 feet thick, forming the Horse Road rock. This sandstone is regarded as part of the Cementstone division,* for on examining the cliffs, we find coming on above it about 300 feet of greyish green shales, thin sandstones, and cementstones.

It is possible that the fault just referred to, may have thrown out from the coast section, not only beds belonging to the Cementstone and Scremerston divisions, but also others on the horizon of the Fell sandstones, and lavas and tuffs representing the volcanic series of Dunbar and North Berwick. There is near Branxton a considerable thickness of deep red, probably stained, sandstones, and the lower of these may be on the horizon of the Fell Sandstones. In considering the possibility of finding workable coals belonging to the Scremerston division in some inland locality on the north side of the fault, it has to be noted, that in Dunglass dean a smaller thickness of coal-bearing beds has been preserved than on the shore.

Near Oldhamstocks, on the south side of the fault above referred to, there is, besides a basic intrusive rock, rich in olivine, a considerable thickness of bedded ash, and some highly vesicular igneous rocks, which are probably lava flows, and it seems likely that these belong to the Cementstone division, and are nearly on the same horizon as the volcanic rocks of Dunbar. Ashy sandstones and vesicular igneous rocks, probably representing lava-flows, are seen in the Cementstone division on the shore

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*The Calciferous Sandstone series of the Borders is often separable into the following divisions, beginning at the top :—

1. Calciferous Division. with marine limestones.
2. Scremerston, or Carbonaceous, Division.
3. Fell Sandstones.
4. Cementstone Division.

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Mr. Clough. nearly a mile east of Dunbar, and ash, probably in the same division, occurs in the railway cutting near Broxmouth.

A little above the limestones of Cove harbour there comes a thick, massive, rather coarse, yellow or red, sandstone, 60 or 80 feet thick, and then a greyish green or purple clay with a thin oil shale, about a foot thick, at the top. This shale is well seen north of the harbour, and also near the mouth of Dunglass dean, the intermediate shore section being occupied by higher beds. This shale is the only oil shale known in the district, and it is probably on the horizon of one of the workable shales of the Lothians, but the beds above and below it are very false-bedded, and it has not been seen in places where we expected to find it, near the foot of Bilsdean and further north-west.

A coal, about 10 inches thick, occurs a little above the limestone at Linkhead and was formerly worked along the outcrop for local use. It seems probable that this coal improves in quality inland, or else that in some places it is accompanied by another coal of more value, for on the shore about a quarter of a mile south east of Linkhead there are the mouths of two old levels which have been driven in a south-west direction, and in a field a considerable distance from them, and on the south-west side of the railway line, there appears to have been shafts which were connected with these levels. These old workings are said to have ceased about a hundred years ago. The coal worked is reported to be 4 feet thick, but no trustworthy information about it can be obtained.

In the Broxmouth railway cutting there is about 150 feet of white and red sandstone at the top of the Calciferous Sandstone series. On the coast north of Thorntonloch, the lowest limestone of the Carboniferous Limestone series is found on the north side of a fault hading north, but the sandstone on the south side is like that referred to in the railway cutting, and it is not probable that many beds are faulted out.

Mr. Barrow. *North Berwick District.*—A striking feature of this area is the great amount of igneous material present, mainly of volcanic character, but partly in the form of plugs. The clastic rocks vary much in composition, though in all but the higher divisions fragmental igneous material is present, and one important zone consists mainly of true volcanic ash. The divisions of the clastic rocks are as follows in ascending order:—

GROUP I.

(*a.*) The lowest rocks consist of soft red and white sandstone with a large amount of hard red sandy marl, and softer red and pink marls, which are seen on the coast north of the Tyne mouth.

(*b.*) The lumpy "Agglomerate" is associated with part of the last group on the shore due east of Whitekirk, and forms extensive scars which weather into large rounded masses. The matrix is a red sandy marl or a fine pink marl, the latter with distinct bedding, while in the former,—the more common type,—the bedding is often difficult to determine. Numerous fragments of marl and marly sandstone occur in it, as well as rarer pieces of igneous material. The rock is usually so soft that it has not been ascertained if fragments of the typical ash occur in it or not. At the top of this zone there is a hard white sandstone which often lies in eroded hollows.

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(*c.*) Soft red sandstone and red and salmon-coloured marls, often showing well-marked parallel bedding, and forming parallel scars on the coast. This zone contains much fewer derived fragments than (*b*), and less recognisable igneous material. The weathering of the sandstones, however, suggests that they are somewhat ashy. Mr. Barrow.

(*d.*) The Green Ash is typically developed on the cliffs and shore for some distance east of North Berwick. Where the ash is fairly pure, it is cemented by lime set free by decomposition of the fragments of basic rock (often a vesicular glass originally) of which the ash is composed, and there is a development of chlorite that colours the rock green. At Seacliff a homogeneous mass of this ash was pierced for 170 feet without proving either the top or bottom. In many cases, however, the green ash contains a vast number of fragments of all sizes. Most of the harder material is well rounded, but large angular fragments of green ash and sedimentary material occur locally. At the base of this zone a bed of limestone often occurs, and has been quarried in several localities, as, for instance, in the Rhodes quarry near North Berwick; but it does not occur on the coast, though it may be represented by a few calcareous bands.

Immediately above the green ash are some mottled red and green ashy beds, associated with soft green and dark mudstones, which are accompanied with thin bands of hard, often cherty, limestone, but the whole group is so soft that little of it is seen on the coast. A portion of these beds is seen to the west of North Berwick Bay, and a boring in the town proved a considerable number of the thin calcareous bands.

(*e.*) Next in order comes a series of red sandstones and pink and red marls, seen in North Berwick Bay and east of Kirkness, which are often agglomeratic, but the bulk of the irregularly shaped fragments are of marl or sandstone. Many of the harder fragments are well rounded. Microscopic sections show that the sandstone contains fragments of ash originally identical with the material of the green ash, but stained red. A feature of these red sandstones is the number of grains of fresh microcline which they contain; indeed it seems to occur in all the red sandstones, but is specially abundant at this horizon. At the top of these red sandstones and marls most of the volcanic sheets occur, though it has not been proved that they keep exactly to one horizon.

(*f.*) At the west end of the sandy shore east of North Berwick, the highest of the volcanic sheets is surmounted by some 30 feet of ash, associated with fine marl, and apparently baked by the igneous rock. The ash is remarkable for the rapid change in colour of the various bands composing it.

GROUP II.

(*g.*) Above the ashes last referred to, is a yellow agglomerate, or breccia, of variable composition, which appears to be the lowest bed that contains well rounded fragments of the undoubted volcanic sheets. It contains also decomposed fragments identical in aspect with the decomposed trachyte, the intrusive nature of which, in many localities, is indisputable. These suggest the presence of an important break.

(*h.*) Next in order come some dark shales with thin beds of red weathering impure ironstone, which are very persistent and form a series of minute but rigidly parallel scars. They occur on the west side of the woods that stretch from Dirleton to the coast.

(*i.*) Calcareous sandstones and marls, which are separated from zone (*h*) by a fault which may have a large downthrow. Similar rocks occupy the shore in the area north of Gullane for a considerable distance. They often appear ashy, but when baked so that the fragments in them are preserved, it is seen that the latter, whether angular or rounded, are not as a rule of igneous origin. Some bands do contain igneous fragments, but it is possible that these have been supplied by ordinary denudation. Fragments of the volcanic sheets often occur in the sandstones and purple marls. Some black shale and thin ironstones occur in the middle of the long outcrop of these calcareous sandstones, and part of the shale is a true oil shale. The latter underlies calcareous sandstone, and may possibly be a bed in zone (*h*), though in the main outcrop of this zone no bituminous shale is seen.

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Mr. Barrow. The igneous rocks of the district, excluding the ash beds, are divisible into three groups, as follows:—

1. The oldest group, consisting of volcanic sheets.
2. The trachytic rocks.
3. The black basaltic rocks, more recent than either of the above.

1. The volcanic sheets are basic or intermediate rocks. The most basic often contain large augite crystals enveloping grains of olivine. Porphyritic felspars are present in all but one or two varieties, and at times are so abundant as to give a character to the rock. A peculiar feature of some of the sheets is the occurrence of much felspar and a great deal of olivine but very little augite. There is one type of rock, which forms the mid band of the North Berwick breakwater and may be called the Congleton rock, which contains few, and often no, porphyritic crystals and is the least basic of the series. It can be easily identified as it shows unusual characters both in the field and under the microscope. The top of it is always slaggy and at times exceptionally so.

2. *The trachytes.*—An excellent description of some of the trachytes has already been given by Dr. Hatch.* An examination of specially fresh material suggests that green (soda) augite is a more persistent component of these rocks than was formerly supposed. All these rocks occur as bosses, or as intrusive sheets given off from them. As a rule the sheets do not extend far from the parent stock.

3. The black weathering basaltic rocks have not yet been seen to intrude into rocks of group (2) though they pierce rocks far above these. They usually occur in the form of sheets or sills which have been fed from a great number of separate bosses, fine examples of which are seen in some of the islands off the North Berwick coast. In composition they range from olivine-dolerite, or basalt, with very little felspar to a dolerite with no olivine and an excess of felspar.

Mr. Bailey. *Haddington and Gifford District.*—At Yester, where beds of the Calciferous Sandstone series come against the Upper Old Red Sandstone, there is no sign of the Cement-stones elsewhere met with at the base of the Carboniferous system, and probably they have been cut out by the Lammermuir fault. The beds next the fault on the N.W. side, are ashes and ashy sandstones, which are, in all probability, on the horizon of the Garlton volcanic rocks. Above the ashes comes a series of sandstones and clays, mostly white but occasionally red, followed by a thick series of sand-stones and clays with thin coals and oil shales, well exposed in the Sandersdean Burn. Here, about midway in the series, a thin encrinital limestone occurs and is perhaps on the same horizon as a similar bed at Inglisfield.

* "The Lower Carboniferous Rocks of East Lothian (Garlton Hills)." *Trans. Roy. Soc. Edin.* vol. xxxvii. part 1. p. 115.

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## CARBONIFEROUS LIMESTONE SERIES.

*Dunbar and Cockburnspath District.*—In the Carboniferous Limestone series there are eight or nine limestones, to which local names are given as indicated in the following section, in which the highest beds are placed at the top. The details given are chiefly obtained from the coast between Barness and Thorntonloch :— Mr. Clough.

| | |
|---|---|
| Barness* east limestone | from 2 to 6 ft. |
| Strata, chiefly sandstone | 50 ft. |
| Dryburn Foot impure limestone or calcareous sandstone, not always present | from 1 to 2 ft. |
| Sandstone and shale | 10 ft. |
| Chapel Point limestone | 9 or 10 ft. |
| Shale and thin coal smut | 3 ft. |
| Fireclay and sandstone | 20 ft. |
| Shale and thin flaggy sandstone | from 70 to 80 ft. |
| Skateraw upper limestone | from 1 to 2 ft. |
| Black Shale | from 3 to 5 ft. |
| Skateraw middle limestone | from 16 to 18 ft. |
| Coal | from 4 to 6 ins. |
| Fireclay | 1 ft. 6 ins. |
| Shale and fireclay | 6 ft. 6 ins. |
| Skateraw lower limestone | from 2 to 4 ft. |
| Shale and sandstone | 23 ft. |
| Long Craig upper limestone | 18 ft. |
| Shale, partly sandy | from 2 to 5 ft. |
| Thin coal in places. | |
| Long Craig middle limestone | 3 ft. |
| Shale and sandstone | 25 ft. |
| Long Craig lower limestone, mixed with bands of calcareous shale | 27 ft. |

The Long Craig lower limestone is seen better in the railway cutting near Broxmouth, where it is vertical, than on the shore. The Long Craig upper limestone and the Skateraw middle limestone are of much the same thickness, but they can generally be readily distinguished, the latter limestone being of a dark grey colour and evenly bedded, while the former is of a creamy colour with knobby bedding surfaces. Throughout this district, also, there is always, a little below the top of the Skateraw middle limestone, a band, 1 or 2 feet thick, crowded with *Saccammina Carteri*, while in the Long Craig upper limestone there is a band, 4 or 5 feet from the top, half made up of some cup coral, apparently a species of *Cyathophyllum*. The Skateraw lower limestone is dark and impure, and generally characterised by *Productus giganteus*. The interval between the Chapel Point limestone and the Skateraw upper limestone is considerably greater than that between any of the other limestones. In the Chapel Point limestone, near the middle, there are in some places thin lenticles of dark chert containing foraminfera large enough to be seen by the naked eye.

About 60 or 70 feet of beds, chiefly sandstone, are seen above the Barness east limestone at Barness, and also above the crinoidal sandstone which seems to represent this limestone on

* This is the name given in the six-inch maps to the point east of Catcraig.

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Mr. Clough. the shore west of Broxmouth. In both these localities the strata are probably very near the base of the Edge coals of Midlothian, and, as the dip of the beds is seaward at angles varying between 5° and 15°, it is probable that a succession of coal-bearing beds outcrop under the sea at a comparatively short distance from the shore. The beds in the locality near Broxmouth are near some large faults and considerably disturbed, but between Barness and the base of the Carboniferous Limestone series near Thorntonloch there is not much disturbance, and it would probably be worth while to prove whether there are not under-sea coals which could be advantageously worked. In the Admiralty Chart (234 New Series) the 20-fathom line passes rather more than a mile and a half E.N.E. of l.w.m. at Barness.

Dr. Crampton. *Aberlady and Keith District.*—The beds in Aberlady Bay are shown in the following section, in descending order:—

| | |
|---|---|
| Compact tough limestone with *Productus*; supposed to be the Skateraw lower limestone | from 3 to 4 ft. |
| False-bedded white sandstone | 4 ft. |
| Sandy black shale | 8 ft. |
| Calcareous shale | 3 ft. 6 ins. |
| Dark blue compact limestone, 8 feet, full of polyzoa, etc., overlying a nodular encrinite limestone from 8 to 10 feet, with a few specimens of *Productus giganteus*. The two bands together are supposed to represent the Long Craig upper limestone | |
| Coal | 10 ins. |
| Grey shale and fireclay | 6 or 7 ft. |
| Coral limestone full of *Lithostrotion junceum* and *Lithostrotion irregulare*, and many other fossils; (probably the Long Craig middle limestone) | 8 ft. |

It is difficult to separate and draw definite boundaries for the limestones inland, owing to the thick superficial deposits which cover the ground almost everywhere, but the different bands are recognisable in some of the quarries.

Mr. Bailey. *Haddington and Gifford District.* South-east of the main outcrop, the lowest limestone of the Carboniferous Limestone series appear to form two outliers, one near Lennoxlove and another near Kidlaw. A quarry in the Lennoxlove limestone shows about 18 feet of argillaceous limestone, with *Productus longispinus*, crinoids and other fossils.

The limestone at Kidlaw has been extensively quarried, but the whole mass is so much broken and disturbed that it seems quite possible that it has been transported by ice. The characteristic *Saccammina Carteri* band of the Skateraw middle limestone has been recognised in numerous fragments. At Skateraw this band occurs more than 100 feet above the base of the Carboniferous Limestone series, and its presence at Kidlaw furnishes an additional reason for doubting whether that exposure is a normal outlier.

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## PLEISTOCENE.

### *Glacial and Post-Glacial Deposits.*

*Dunbar and Cockburnspath District.*—A considerable proportion of the Drift is of a light gravelly character. In various coast sections beds of sand and gravel are exposed between reddish Boulder Clay, and near Oldhamstocks there is a great mass, perhaps 80 feet thick in places, of sand and gravel resting on Boulder Clay; a considerable part of the gravel seems derived from beds of conglomerate like those in the high-lying Old Red Sandstone area to the west. Mr. Clough.

In the drift-covered area there are various long banks and valleys which run from N.W. to S.E., and which are, perhaps, the result of erosion by marginal ice-streams. Many are cut by deep deans which fall in a N.E. direction.

Near Oldhamstocks there is a series of almost flat, wide-spread terraces of gravel. The highest is about 100 feet above the present burn, and its east limits are not well defined.

The 20-feet raised beach is seen in many places, and there are also various higher terraces near the coast, and reaching to heights of about 100 feet, but these last are only distinct near the mouths of burns, and it is not certain that they are due to marine erosion.

*North Berwick District.*—During the melting away of the ice sheet, streams were formed which have left their impress on many of the scars and rock faces between East Linton and Drem. Mr. Barrow.

The distribution of the marine sand at various altitudes round the coast, and its absence at similar altitudes in the interior, suggest that, a little inland, a small isolated cake of ice loaded with mud prevented the ingress of the sea and the formation of the 75-feet and 100-feet raised beaches.

*Aberlady District.*—The 25-feet and 100-feet raised beaches cover the solid rocks from Aberlady Bay inland as far as Spittal, near the railway line. In one place, on the Gosford Park Estate, blue clay, 25 feet thick, has been proved by a boring starting at a level of about 50 feet above the sea. Dr. Crampton.

*Haddington and Gifford District.*—Boulder Clay covers almost the whole district except where the streams have laid down tracts of alluvium, or where, along the Lammermuir flanks, the drift gravels are heaped up. It may be red and sandy, blue or faint bluish white, and encloses blocks of Carboniferous sandstone and coal, igneous rocks, and occasionally Highland metamorphic rocks. It also contains angular masses of soft sand, not unlike pseudomorphs after ice fragments. Silurian stones are absent, and big blocks of any kind are rare. Mr. Bailey.

Great terraces of sand and gravel are banked up against the Lammermuirs, and contain many sub-angular pieces of Silurian shale and greywacke. The terraces of gravel in the great recession which holds the tributaries of Gifford Water, reach up along the courses of the burns into Silurian territory, and they were in all probability deposited in water held up against the Lammermuirs by the retreating ice-sheet.

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Mr. Bailey. No striæ have been observed in the country between Haddington and the Lammermuirs. There is, however, a series of features, running N. of E.N.E., which seem to be the result of ice moulding. The valleys among them now often hold small burns, and not infrequently are spread over with sand and gravel. Though the features are cut in solid rock they are swathed almost completely in Boulder Clay. This might be explained, perhaps, by supposing that the modelling was the result of marginal-ice streams during an advance or oscillatory retreat of the ice. So also might the fact that of the two hollows bounding Monkrig, the one further up the main valley is the deeper. The valley features above described, in some cases at any rate, terminate in the Tyne valley, two miles below Haddington. It is obvious that if these features are due to ice moulding, yet in the retreat of the glaciers they must often have furnished channels for the escaping waters.

## ECONOMIC FEATURES.

Mr. Clough. Most of the area is highly cultivated, and perhaps as fertile as any part of Scotland. The richness of the soil about North Berwick and Dunbar is generally attributed to the great amount of igneous and ashy material which it contains.

*Dunbar and Cockburnspath District.*—Various statements concerning the possibility of finding workable coal have been already made in connection with the solid geology.

The only limestone now being quarried for burning is the Skateraw middle limestone; the quarry is near Oxwellmains, and at present about half the stone quarried is being sent to smelting furnaces in the West of Scotland. The Chapel Point limestone is sometimes quarried on the shore at Chapel Point, but only on a small scale and for road metal.

The Billsdean sandstone, which comes above the Cove oil shale, is exposed for a considerable distance along the shore and in Dunglass dean, and was once largely quarried. It furnished the stone of which Dunglass mansion house was built, and makes an excellent building stone, in most parts of a white or pale yellow colour, and is very easy to work and yet durable. The red sandstones near Branxton and Thornton were also at one time extensively wrought.

Cockburnspath and Oldhamstocks, and many farms, are supplied with water pipe from springs a short distance off. Many of these springs certainly issue from glacial sands and gravels lying over Boulder Clay, but no systematic investigation of them has been made.

Mr. Barrow. *North Berwick District.* The richness of the soil about North Berwick has led to the cultivation of almost the whole country, and there are few permanent pastures except the home parks around the large houses. The glacial sands form a poor soil much of which is planted, and here and there stiff Boulder Clay occurs which is not very profitable to work.

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Mr. Barrow.

Of the igneous rocks, only the trachytic, such as the rock of North Berwick Law, have been used to any considerable extent as building material. The few beds of sandstone that are bare of drift are for the most part too soft for the construction of house walls. Almost any of them, however, make good field fences.

The black basaltic intrusive rocks make excellent road metal and have been largely quarried. A big quarry has been opened in the light grey non-porphyritic variety of trachyte, which is well suited for the purpose if taken some depth below the surface and broken small by machinery. The volcanic sheets are said not to form good road metal, as they split into flakes parallel to the bedding, and these when rolled tend to arrange themselves parallel to each other and do not bind together. But this difficulty could, perhaps, be overcome if the rocks were broken smaller by machinery; at present much of it is broken by hand.

The rocks do not seem to give an abundant water supply, and the water for North Berwick is piped from the Silurian uplands to the south. This is, perhaps, partly due to the smallness of the area, free from drift, into which water can sink, and to the absence of high ground to give a head to any water that may accumulate in the rocks. Where possible, the large farms are supplied by the North Berwick Water Company, in preference to having wells of their own.

Dr. Crampton

*Aberlady District.*—The only quarry of limestone that is at present being worked is that at Harelaw, Longniddry.

Mr. Bailey.

*Haddington and Gifford District.*—Coal used to be wrought in Sandersdean, but the workings are now discontinued. At Kidlaw, on the flank of the Lammermuirs, the limestone quarries have been abandoned, but there is a large quarry of basalt which provides excellent road metal and is very widely used in the neighbourhood.

For water supply Haddington relies upon two sources, one the sandstone cropping out on the side of Whitelaw Hill, and the other the great drift gravels which fringe the Silurian area and which have been tapped at Long Yester.

## II. Palæontological Work.

Dr. Peach.

The Palæontological department in Scotland was carried on by Dr. Peach, with the assistance of Mr. A. Macconochie and Mr. D. Tait. As in former years, valuable assistance has been cordially given by Dr. Traquair, Dr. Wheelton Hind, and Mr. R. Kidston. The total number of fossils collected during the year and entered in the Survey List Books is 2,491.

Fossils to the number of 1,129 have been named and entered up in the list books during the season. Of these, only eighty-five from the Campbeltown Coal Field and the Lower Carboniferous rocks of Berwickshire were named by Dr. Peach. All the others have been determined by the following specialists to whom the thanks of the Geological Survey are due.



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Dr. Peach. Dr. Traquair has named 270 fishes from the Ludlow and Downtonian rocks, several of which have been figured by him. He has further supplied the following report upon the new points of morphological interest which they exhibit:—

Dr. Traquair. "Among the fish remains collected by Mr. Tait during the past summer in the Upper Silurian rocks of the Lesmahagow district and submitted to me for determination and comment, are two which exhibit new points, which are eminently worthy of notice.

"*Lanarkia*, sp. undet. A fragment showing the front of the head and part of the body, referable to this genus on account of the dermal armature which consists of minute spines, along each lateral margin, are indications of a row of pouch-like structures exactly in the position of the supposed branchial pouches of *Cyathaspis*. The close affinity between the Cœlolepidæ and Pteraspidæ receives here a striking confirmation.

"*Lasanius problematicus*, Traq. A fragment of a large specimen from Birkenhead burn, showing the nuchal long rods, and a portion of the integument behind them. On wetting the specimen, the integument at once shows an obliquely striated appearance, apparently due to the presence of very delicate narrow band-like calcifications or hardenings, which run parallel with the nuchal rods, and consequently in a direction similar to that of the narrow body scales of *Birkenia*. This is fresh evidence in favour of the affinity of those two remarkable genera."

Dr. Traquair has also named thirty-three specimens of fishes from the Carboniferous rocks of Midlothian.

Dr. Peach. At Mr. Kynaston's request, Dr. Peach and Mr. Tait accompanied Mr. Kynaston to Glencoe and made a collection of fossils from some dark shales that lie near the base of the great volcanic plateau on the flanks of the Buachille Etive Mor. Mr. Tait there found specimens of the Lower Old Red Sandstone plants *Psilophyton* and *Pachytheca*—the *Œtheotesta devonica* Dawson—which determine the horizon of this volcanic plateau to be the same as that of Lorne and of the Ochil Hills. The specimens of *Pachytheca* are well preserved and show structure; the best of these have been placed in the hands of Mr. Kidston for future microscopic investigation. Regarding some of the specimens of *Psilophyton*, Mr. Kidston reports that the specimens were very fragmentary and could not be specifically identified, but they possess all the characters of small branchlets of *Psilophyton*. Mr. Kidston has further named 692 specimens of plant remains from the Carboniferous rocks of Berwick, Haddington and Dumfries.

A small collection of plants remains, made by Mr. Macconochie from the Campbeltown Coal Field, and a further collection made by Mr. McPherson, C.E., and forwarded by Mr. Lindsay Galloway to the Geological Survey, were submitted to Mr. Kidston who supplied the following notes and lists which corroborate the view hitherto held that the Campbeltown Coal Field is on the horizon of the "Edge Coals" of the Midlothian Basin.

Mr. Kidston. In all, three collections were submitted to Mr. Kidston for examination, which are referred to in the following report:—

"The first specimens were sent me by Mr. T. Lindsay Galloway, from the shale of the Main Coal, but were badly preserved and threw no light on the age of the rocks from which they were derived.

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"The second lot was collected by Mr. A. Macconochie, some of which were from the same band, but in addition, he discovered a thin band of shale interleaved in sandstone cropping out in Machrihanish water, 320 yards west of pit, which contained some well preserved specimens, and the third collection was made later from the same band by Mr. McPherson, C.E., which was forwarded to the Geological Survey by Mr. Galloway. Mr. Kidson.

Only one specimen could be specially identified in Mr. Galloway's first collection :—

*Stigmaria ficoides*. Sternb. sp.
*Loc.* Wimbledon Pit, Machrihanish, near Campbeltown.
*Hor.* Roof of Kilkivin Seam.

The following were collected by Mr. Macconochie.

I. From Wimbledon Pit, Machrihanish.
*Hor.* Shale resting on Main Coal.

*Sphenopteris elegans*, Brongn. (rare).
1822. *Filicites* (*Sphenopteris*) *elegans*, Brongn. Class. d. végét. foss. p. 33. Pl. ii., figs. $2^a$, $2^b$.
1830. *Sphenopteris elegans*, Brongn. Hist. d. veget. foss. p. 172. Pl. LIII., figs. 1-2.
1877. *Diplothmema elegans*, Stur, Culm Flora, Heft ii., p. 130 (236). Pl. xiii., fig. 5, Pl. xiv., figs. 1-6.
1853. *Sphenopteris johnstoniana*, Tate in Johnston's Nat. Hist. of Eastern Borders, vol. i., p. 306, figs. 1-2.

*Sphenopteris Linki*, Göpp. sp. (very plentiful).
1836. *Gleichenites Linki*, Göpp. Syst. fil. foss. p. 182. Pl. i., fig. 1.
1845. *Sphenopteris Linki*, Unger. Synop. plant. foss. p. 67.
1877. *Calymmotheca Linki*, Stur. Culm Flora, Heft ii., p. 161 (267) Pl. xiii., figs. 1, $1^a$, 2, 3, 4, $5^a$, $5^b$, 6.
1836. *Cheilanthites microlobus*, Göpp. Syst. fil. foss. p. 238. Pl. xiii., figs. 1-3.

*Lepidodendron veltheimianum*, Sternb.

*Lycopod macrospores.*

II. *Loc.* Bed of burn, Tirfergus Glen, at Limestone Section.
*Hor.* In sandy shale underlying the lower coal at Limestone Section.
*Sphenopteris Linki*, Göpp. sp.
*Sphenopteris elegans*, Brongn.

III. *Loc.* Machrihanish Water, 320 yards west from Wimbledon Pit.
*Hor.* Shale interleaved in Sandstone.
*Sphenopteris Linki*, Göpp. sp. Very plentiful.
*Sphenopteris elegans*, Brongn. Rare.
*Sphenopteris*, sp.
*Diplotheca stellata*, Kidston, n.g. et sp.

This last is a fern fructification allied to *Calymmatotheca*, Stur, but differs in the long linear *sporangia*, being united at the base in pairs. Six pairs of germinate *sporangia* spread starlike from a common point of attachment, giving the fossil much the appearance of a whorl of *Annularia* leaves.

The third collection was that made by Mr. McPherson, C.E.
*Loc.* Machrihanish Water, 320 yards west of Wimbledon Pit.
*Hor.* Shale interleaved in Sandstone.
*Sphenopteris Linki*, Göpp. sp. Very plentiful.
*Cardiopteris polymorpha*, Göpp. sp. *var. rotundifolia*, Göpp.

Of this last there was only a single pinnule.

The total number of species collected is small, but is sufficient to prove the Lower Carboniferous Age of the Coal Field, and I believe assign to it the definite position of the 'Edge Coal Series.'"



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Dr. Peach. Early in the season the sections of the Carboniferous rocks exposed on the Berwickshire, Haddington, and Fife coasts were traversed for the purpose of familiarising the members of the Geological Survey with the order of succession of those beds, prior to the revision of the coal fields in the autumn. During one of these traverses Mr. Tait discovered on the Abden shore a bed of ash full of plant remains on the horizon of the Abden Limestones near the top of the Calciferous Sandstone series One of the specimens proved to be the remains of a fern new to Britain. Later in the season Mr. Kidston and Mr. Macconochie made collections from various localities in Fife, including the bed near Abden. These are referred to by Mr. Kidston in the following report:—

Mr. Kidston. "During the summer of 1902 the Calciferous Sandstone series of Fife was, at several localities, examined for fossil plants, which resulted in the discovery of some interesting species, a few of which had not previously been met with in Britain. On several of these excursions I had the assistance of Mr. Macconochie.

"Appended is a list of the localities which yielded fossil plants and the species which were collected from them:—

I. Shore about three-quarter mile N.N.E. of Kinghorn, almost immediately below the Combination Poor House.

The specimens were preserved in a fine Tuff.

*Horizon.* Near the top of the Calciferous Sandstone series, a short distance below the Hurlet Limestone.

The beds containing the fossils are formed of fine volcanic ash, and one of the beds from which some of the specimens were collected appears to have been only a small lenticular patch. The plants often lie obliquely to the bedding—their lower portion having been held in the mud while the upper part was floating in the water; the specimens thus frequently pass through more than one thin bed, which makes it impossible to secure complete examples.

The fossils at this locality were collected from two, if not three distinct beds, which were, however, separated from each other by only a short distance, probably not more than 2 or 3 feet, but owing to the distortion and bending of the strata, it was difficult to trace the beds, and, in fact, as already mentioned, some of them almost appeared as if they had been deposited in hollows of small extent.

The lower bed may be distinguished as Bed 1, and the uppermost as Bed 2.

This locality was first discovered by Mr. D. Tait.

Specimens from Bed 1:—

*Rhacopteris paniculifera*, Stur.

1875. *Rhacopteris paniculifera*, Stur, Culm Flora, Heft i. p. 72, Pl. viii., fig. 3.

This species is somewhat closely related to *Rhacopteris inæquilatera*, Göpp. sp. (*Adiantites lindseæformis*, Bunbury). It was not uncommon in this bed, and is a species I have not previously met with in Britain.

The late Mr. Charles Peach mentions having found *Rhacopteris paniculifera* at "Slateford, West Calder, etc.,"* but I am afraid there must be some mistake in these records, as I have never seen the plant either in the collection of the late Mr. Charles Peach or in any other collection which I have examined.

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* *Trans. Bot. Soc. Edin.*, vol. xiii., p. 47.

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Mr. Kidston.

*Rhacopteris transitionis*, Ett. sp.

1865. *Asplenites transitionis*, Ett. Foss. Flora. d. Mährisch-Schlesischen Dachschiefers, p. 23, fig. 8 (Denksch. d. Math. Naturwiss. Classe d. Kaiserl. Akad. d. Wissensch. vol. xxv.).

1875. *Rhacopteris transitionis*, Stur. Culm Flora. Heft i., p. 77, pl. viii. figs. 5 7; Heft ii., p. 319, pl. xv., fig. 14, 1877.

Several specimens were collected, but owing to their lying obliquely to the bedding, good specimens were difficult to procure.

*Alcicornopteris* sp.

A single example of a small species was met with. It is more delicate in all its parts than either *Alcicornopteris Zeilleri* Vaffier,* or the *Alcicornopteris convoluta*, Kidston,† and is, I believe, a new species.

Specimens from Bed 2.

*Sphenopteris* n. sp.

*Sphenopteris* sp. indeterm.

A few specimens were got from a third bed, which, as far as could be determined from the twisted and irregularly bedded strata, seemed to occupy a position between Beds No. 1 and No. 2.

*Rhodea moravica*, Ett. sp.

1865. *Trichomanes moravicum*, Ett. Foss. Flora d. Mährisch-Schlesischen Dachschiefers, p. 24, fig. 9, pl. vi., fig. 4.

1875. *Rhodea moravica*, Stur, Culm Flora, Heft i., p. 38, pl. x., figs. 3–7; pl. xi., fig. 1.

1877. *Calymmotheca moravica*, Stur. Culm Flora, Heft ii., p. 278. Rare in the bed.

*Rhacopteris inæquilatera*, Göpp. sp.

1860. *Cyclopteris inæquilatera*, Göpp. Foss. Flora d. Silur., Devon. u. unter. Kohlenf., p. 72, pl. xxxvii., figs. 6–7.

1861. *Adiantites Lindseæformis*, Bunbury. *Geol. Survey of Great Britain:* The Geology of the Neighbourhood of Edinburgh, pp. 144, 151, fig. 26.

Also rare in this bed.

*Rhacopteris* sp.

*Sphenopteris crassa*, L. & H.

1835. *Sphenopteris crassa*, L. & H. Fossil Flora, pl. clx.

1883. *Sphenopteris crassa*, Kidston, *Proc. Roy. Phys. Soc. Edin.*, vol. vii., p. 235, pl. v., figs. 1–2.

1875. *Sphenopteris Kiowitzensis*, Stur, Culm Flora, Heft i., p. 32, pl. vi., fig. 8.

Several specimens were collected, but all in a fragmentary condition owing to the specimens lying somewhat obliquely to the bedding.

II. Shore, Breakboats, Pittenweem. Bed No. 367 of Mr. Kirkby's List.

*Horizon.* In sandy shales, a little above Encrinite bed and 2,152 feet below Hurlet Limestone.

*Sphenopteris pachyrrhachis Göpp.* var. *stenophylla, Göpp.*

1852. *Sphenopteris pachyrrhachis* var. *stenophylla, Göpp.* Foss. Flora d. Uebergangs., p. 143, pl. xiii., figs. 4–5.

*Calymmatotheca affinis*, L. & H. sp.

1832. *Sphenopteris affinis*, L. & H. Fossil Flora, vol. i., pl. xlv.

1887. *Calymmatotheca affinis*, Kidston, Trans. Roy. Soc. Edin. vol. xxxiii. p. 137, pl. ix., figs. 18–22.

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* Étude géologique et paléontologique du Carbonifère Inférieur du Maconnais, p. 125, pl. vi. fig. 5; pl. viii., figs. 1, 1*a*, 1*b*, 1*c*, 1*d*, 1*e*, 1*f* (Annal. d. l'Université de Lyon. Nouv. sér. i., Sciences, Médicine, fasc. 7, 1901).

† *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 152, pl. viii., figs. 11–15, 1887.

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Mr. Kidston. *Asterocalamites scrobiculatus*, Schl, sp.

1820. *Calamites scrobiculatus*, Schlotheim. Petrefactenkunde, p. 402, pl. xx., fig. 4.
1828. *Calamites radiatus*, Brongn. Hist. d. Végét Foss., p. 122, pl. xxvi. figs. 1–2.
1852. *Calamites transitionis*, Göpp. Foss. Flora d. Uebergangs. p. 116, pl. iii. figs. 1–6 (? fig. 7).
1862. *Calamites* (*Asterocalamites*) *radiatus*, Schimper, Terr. d. Trans. d. Vosges, p. 321, pl. i.
1875. *Archæocalamites radiatus*, Stur, Culm Flora., Heft i., p. 2, pl. i. figs. 3–8; pl. ii., pl. iii., pl. iv., pl. v., figs. 1–2; Heft ii., y. 180 (74), pl. ii. (xix.), figs. 1–6; pl. iii. (xx), figs. 1–2; pl. iv. (xxi.), figs. 1, 1*b*; pl. v. (xxii.), fig. 1.

*Lepidophloios Scoticus*, Kidston.

1885. *Lepidophloios Scoticus*, Kidston, Ann. & Mag. Nat. Hist., Ser. 5, vol. xvi., p. 137, pl. vii., fig. 14.
1893. *Lepidophloios Scoticus*, Kidston, Trans. Roy. Soc. Edin., vol. xxxvii., p. 561, fig. p. 551; pl. i. figs. 2, 3; pl. ii. figs. 5–7.

III. Right bank of Cameron Burn, quarter of a mile east of Stravithie Mill, near St. Andrews.

*Horizon.* In Limestone Bed about the horizon of the Burdiehouse Limestone.

*Bothrodendron Depereti*, Vaffier.

1901. *Bothrodendron Depereti*, Étude géol. et paléont. du Carbonifère Inférieur du Maconnais, p. 139, pl. xi., figs. 3, 3*a*, 3*b*; pl. xii., fig. 4, 4*a*.

This species, which has not previously been met with in Britain, is closely related to *Bothrodendron wükianum*, Kidston,* but is distinguished by its larger size and the ornamentation of the outer surface of the cortex. In *Bothrodendron Depereti*, Vaffier, the striation of the outer surface of the bark is not flexuous, as in *Bothrodendron wükianum*, but runs straight up to the leaf scars both below and above them, whereas in *Bothrodendron wükianum* the striations are more or less flexuous, and are deflected both above and below the leaf scars, bending round them, and thus leaving the scars surrounded by an elongated rhomboidal smooth space.

Only a single specimen was found—

*Lepidodendron Veltheimianum*, Sternberg.

1826. *Lepidodendron veltheimi*, Sternb. Essai flore monde prim., vol. i. fasc, 4, p. 48, pl. liii., fig. 3.
1826. *Lepidodendron veltheimianum*, Sternb. (ibid. I.), i. fasc. 4, p. xii.
1885. *Lepidodendron veltheimianum*, Kidston (in part), Ann. and Mag. Nat. Hist. Ser. 5, vol. xvi., p. 243, pl. iii., pl. iv., fig. 2 (not figs. 3–4,) pl. vi., figs. 11, 11*a*, 11*b*.
1902. *Lepidodendron Veltheimianum*, Kidston, Proc. York. Geol. and Polytech. Soc., vol. xiv., part iii., pp. 347, 381, 383, pl. lvi., fig. 1; pl. lvii., fig. 1.

Not uncommon, especially the smaller branches.

*Cordiates*, sp.

A single fragment of a leaf was collected.

IV. Right bank, Wakefield Burn, quarter of a mile north-east of Dunino sawmill, Dunino, near St. Andrews.

*Horizon.* Arenaceous shale in massive sandstones.

*Calymmatotheca affinis*, L. & H. sp.

Not common in the Bed.

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* Kidston, *Ann. and Mag. Nat. Hist.*, Ser. 6, vol. iv. p. 60, pl. iv., figs. 3–4 (not fig. 2), 1889: also *Proc. Roy. Phys. Soc. Edin.*, vol. x., p. 94, pl. iv., figs. 3–4 (not fig. 2), 1889.

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Mr. Kidston.

*Cardiopteris frondosa*, Göpp. sp.

1852. *Cyclopteris frondosa*, Göpp. Foss. Flora d. Uebergangs. p. 163, pl. xiv. figs. 1-2.

1862. *Cyclopteris Kœchlini*, Schimper, Terr. d. Trans. d. Vosges, p. 340, Pl. xxviii.

1865. *Cyclopteris Haidingeri*, Ett. Foss. Flora d. Mährisch-Schlesischen Dachschiefers, p. 20, fig. 5, Pl. v.

1869. *Cardiopteris frondosa*, Schimper, Traité d. paléont végét, vol. i., p. 453, Pl. xxxv.

The isolated pinnules of this species were very plentiful in a bed of a grey arenaceous shale. In no case did we find the pinnules united to the rachis.

Many years ago, the late Mr. Gibbs, fossil collector to the Geological Survey, met with well preserved isolated pinnules of this species "in bed of burn, Stravithie, four miles south of St. Andrews. We tried to rediscover this bed, but failed to do so. The matrix of those discovered by Mr. Gibbs is a hard reddish sandstone, and his locality could not have been far distant from the bed containing *Cardiopteris frondosa* found by us.

Dr. Peach.

While the revision of the Carboniferous areas was being carried on by Mr. Clough in the region south of Dunbar during the autumn, Mr. Macconochie made collections of plant remains from several horizons. He not only searched the bands recorded by the late Mr. Richard Gibbs and the late Mr. James Bennie, but he discovered several other plant-bearing beds which yielded him a large collection. These have been submitted to Mr. Kidston who supplied the following lists, many of the plants being entirely new to the locality and some of them very rare.

List of Fossil Plants collected by Mr. A. Macconochie from the Calciferous Sandstone series in the neighbourhood of Cockburnspath, Berwickshire, by Mr. Kidston—

Mr. Kidston.

Although none of the plants in this collection are new to Britain except one which I am unable at present to determine, the three following are very rare.

*Sphenopteris subgeniculata*, Stur sp.
*Rhodea machaneki*, Ett. sp.
*Rhodea patentissima*, Ett. sp.

*A Locality.* A quarter of a mile and fifty yards E.S.E. of entrance to Cove Harbour, Cockburnspath.

*Horizon.* Cement-stones of Ballagan series.

*Stigmaria ficoides* var. *undulata* Göppert.

1841. *Stigmaria ficoides* var. *undulata*, Göpp. Gatt. d. foss. Pflanzen lief. 1-2, p. 19, Pl. ix. figs. 5 (? 6), 7, 8, (? 9).

1852. *Stigmaria ficoides* var. *undulata* Göpp. Foss. Flora d. Uebergangs. p. 245, Pl. xxxii. fig. 2.

*B Locality.* A quarter of a mile south-east of Linkhead, near Cockburnspath.

*Horizon.* Grey shale in sandstone, overlying the Linkhead Limestone.

*Sphenopteris subgeniculata*, Stur sp.

1877. *Diplothmema subgeniculatum* Stur, Culm Flora. Heft ii., p. 135, Pl. xii., figs. 8, 9, 10.

1889. *Sphenopteris subgeniculata*, Kidston, Trans. Roy. Soc. Edin., vol. xxxv., p. 424, Pl. ii., fig. 10.

*Rhodea machaneki* Ett. sp.

1865. *Trichomanites machaneki* Ett. Foss Flora d. Mährisch-Schlesischen Dachschiefers, p. 25, fig. 12.

1875. *Rhodea machaneki* Stur, Culm Flora Heft i. p. 34.

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*Rhodea patentissima*, Ett. sp.

Mr. Kidston. 1865. *Hymenophyllites patentissimus*, Ett. Foss. Flore d. Mährisch—Schlesischen Dachschiefers, p. 26, fig. 13, pl. vii., fig. 4.

1875. *Rhodea patentissima*, Stur. Culm Flora, Heft i., p. 36, pl. ix., fig. 1-9.

*Rhodea moravica*, Ett. sp.

1865. *Trichomanes moravicum*, Ett. Foss. Flore d. Mährisch—Schlesischen Dachschiefers, p. 24, fig. 9, pl. vi., fig. 4.

1875. *Rhodea moravica*, Stur. Culm Flora, Heft i., p. 38, pl. x., figs. 3-7; pl. xi., fig. 1.

1877. *Calymmotheca moravica*, Stur. Culm Flora, Heft ii., p. 278.

*Sphenophyllum tenerrimum*, Ett.

1874. *Sphenophyllum tenerrimum*, Ett. mscr. Helmhacker. Beitr. z. Kenntniss d. Flora d. Südrandes d. oberschlesisch-polnischen Steinkohlenform. p. 28, pl. iii., figs. 5-16 (in Berg. u. Hiittenmann. Jahrb., vol. xxxii.).

1877. *Sphenophyllum tenerrimum*, Ett. mscr, Stur. Culm Flora, Heft ii., p. 214, fig. 23 (p. 220), pl. vii. (xx.) figs. 1-14.

*C Locality.* Shore at Standalane, about half a mile S.E. of Linkhead.

*Horizon.* In Clayey Shale beds above Linkhead Limestone and a little above Beds at locality *B*.

*Calymmatotheca affinis*, L. & H.

1832. *Sphenopteris affinis*, L. & H. Fossil Flora, vol. i., pl. xlv.

1877. *Calymmatotheca affinis*, Kidston, *Trans. Roy. Soc. Edin.*, vol. xxxiii., p. 137, pl. ix., figs. 18–22.

Very plentiful and specimens well preserved.

*D Locality.* Bay near Standalane, about half a mile S.E. of Linkhead.

*Horizon.* Bituminous shale resting on thin coal.

*Sphenophyllum tenerrimum*, Ett.

*E Locality.* Ninety yards south of entrance to Cove Harbour, Cockburnspath.

*Horizon.* In shale and in Ironstone band in the shale, on horizon of Scremerston Series.

*Rhodea moravica*, Ett. sp.

*Cardiopteris polymorpha*, Göpp, sp.

1860. *Cyclopteris polymorpha*, Göpp, Foss. Flora d. Silur, Devon, u. unter. Kohlenform. p. 78, pl. xxxviii., figs. $5^a$ and $5^b$.

1865. *Cyclopteris hochstetteri*, Ett. Foss. Flora d. Mährisch-Schlesischen Dachschiefers, p. 21, pl. vi., fig. 3.

1869. *Cardiopteris polymorpha*, Schimper, Traité d. Paléont. végét. vol. i., p. 452.

1875. *Cardiopteris hochstetteri*, Stur, Culm Flora, Heft i., p. 48, pl. xiv., fig. 2 (? fig. 3).

*F Locality.* Shore a little below high water mark, ninety yards south of entrance to Cove Harbour, Cockburnspath.

*Horizon.* About thirty feet below the lowest of the Cove Limestones.

*Sphenopteris dissecta*, Brongn.

1829. *Sphenopteris dissecta*, Brongn. Hist. d. végét. foss. p. 183, pl. xlix., figs. 2-3.

1877. *Diplothmema Schützei*, Stur, Culm Flora. Heft ii., p. 128 (234), pl. xiii. (xxx) figs. $4^a$,—$4_g$.

*Cardiopteris polymorpha* var. *rotundifolia*, Göpp.

1860. *Cyclopteris polymorpha* var. *rotundifolia*, Göpp. Foss. Flora d. Silur. Devon. u. unter Kohlenform. p. 78, pl. xxxviii., figs. $6^a$ and $6^b$,

*Asterocalamites scrobiculatus*, Schl. sp.

1820. *Calamites scrobiculatus*, Schlotheim, Petrefactenkunde, p. 402, pl. xx., fig. 4.

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1828. *Calamites radiatus*, Brongn. Hist. d. végét. foss. p. 122, pl. xxvi., figs. 1 2. Mr. Kidston.

1852. *Calamites transitionis*, Göpp. Foss. Flora d. Uebergangs. p. 116, pl. iii., figs. 1-6 (? fig. 7).

1862. *Calamites* (*Asterocalamites*) *radiatus*, Schimper, Terr. d. Trans. d. Vosges, p. 321, pl. i.

1875. *Archæocalamites radiatus*, Stur, Culm Flora, Heft i., p. 2, pl. i., figs. 3-8; pl. ii.; pl. iii.; pl. iv.; pl. v., figs. 1-2, Heft ii., p. 180 (74), pl. ii. (xix), figs. 1-6; pl. iii. (xx) figs. 1-2; pl. iv. (xxi), figs. 1, 1b; pl. v. (xxii), fig. 1.

*Lepidophyllum lanceolatum*, L. & H.

1831. *Lepidophyllum lanceolatum*, L. & H. Foss, Flora, Vol. i., pl. vii., figs. 3-4.

*G Locality.* Outcrop in slope above Cove Harbour, Cockburnspath.

*Horizon.* Sandstone and red Ironstone band. Same band as locality E.

*Calymmatotheca affinis*, L. & H. sp.

*Cardiopteris polymorpha* var. *rotundifolia*, Göpp.

The isolated pinnules of this fern fill a band of red Ironstone 2 to 3 inches thick.

*Asterocalamites scrobiculatus* Schl. sp.

*Lepidodendron Rhodeanum*, Sternb.

1820. "*Schuppenpflanze*,' Rhode, Beitr. z. Pflanzenkunde der Vorwelt, p. 7, pl. i., figs. 1a, 2, 3, 4.

1826. *Lepidodendron rhodeanum*, Sternb. Essai flore monde prim. fasc. iv. p. xi.

1852. *Sagenaria depressa*, Göpp, Foss. Flora d. Uebergangs. p. 179, pl. xliii., figs. 5-6.

*Lepidophyllum lanceolatum*, L. & H.

*Lepidostrobus* sp.

*H Locality.* Bay north-west of Cove, Cockburnspath.

*Horizon.* Shale resting on oil shale band. About two feet above Lowest Cove Limestone.

*Calymmatotheca affinis*, L. & H. sp.

Dr. Wheelton Hind has named thirty-one specimens of Lamelli- Dr. Peach
branchs from the beds underlying the Campbeltown Coals. The lamellibranchs from the rocks of the Canonbie Coal Field were also submitted to him, and he has named eighteen specimens. The latter corroborate the evidence obtained from the plant remains by Mr. Kidston that the rocks in which they occur are of Coal Measure Age.

The collection of Lower and Upper Silurian trilobites belonging to the Geological Survey, and kept in the Museum of Science and Art, Edinburgh, numbering 346 specimens, has, during last year, been examined by Mr. F. R. Cowper Reed, of the Woodwardian Museum, Cambridge, in connection with his forthcoming monograph to be published by the Palæontographical Society. The value of the collection has thus been much enhanced, as he has revised the previous determinations and brought the nomenclature up-to-date. Mr. Cowper Reed has also examined the small collection of fragmentary trilobite remains from the Durness Limestone belonging to the Survey, and has generously supplied notes upon them.

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### III.—Museum Work.

Mr. Goodchild.

Mr. Goodchild, Curator of the Geological Survey Collections in the Edinburgh Museum of Science and Arts, reports that the Fourth Edition of the *Guide to the Geological Survey Collections* was published early in the year.

In connection with the rock-specimens, a special case has been devoted to the exhibition of a selected series illustrative of the Eruptive Rocks of Tertiary age from Skye, which were arranged with the co-operation of Mr. Harker in accordance with the latest information upon the subject.

Mr. Macconochie has arranged the collections of Scottish Jurassic fossils, and has also indicated by a special mark the zonal forms of the graptolites. Selections of duplicate rock-specimens and fossils have been presented to the Royal College of Science, London; the Universities of Cambridge and Oxford; and to the Corporation of Glasgow for exhibition in the Kelvingrove Museum.

The draft Catalogue of the specimens exhibited in the under cases, referred to in a former Report, has now been completed.

Miss Jane Donald has presented specimens of Scottish graptolites and of Carboniferous fossils from Liddesdale and Arran to the Geological Survey Collection.

Photographic Work.

During the past season Mr. Lunn visited the district round Pitlochry, the valley of the Garry and Strath Tay, included in Sheet 55, and took 103 photographs illustrating the geology of these areas.

## III.--IRELAND.

### FIELD WORK.

#### Belfast District.

Mr. G. W. Lamplugh, District Geologist.
Mr. J. R. Kilroe,
Mr. A. McHenry,
Mr. H. J. Seymour, B.A. } Geologists.
Mr. W. B. Wright, B.A.
Mr. H. B. Muff, B.A.

The mapping of the superficial deposits of the Belfast area was completed during the year and the results will be published on a special map in which Belfast is centrally placed. The area in question extends for eighteen miles in an east and west, and twelve miles in a north and south direction, and is divided into three well-marked physical regions, the boundaries of which cross the map in a general north-east and south-west direction. The north-west portion is occupied by the Basaltic Uplands, the central portion by the Triassic Lowlands or Lagan Valley, of which Belfast Lough may be regarded as an extension, and the south-eastern portion by the Silurian Uplands, whose continuity is interrupted by the Pre-Triassic depression which connects the central valley with Strangford Lough.

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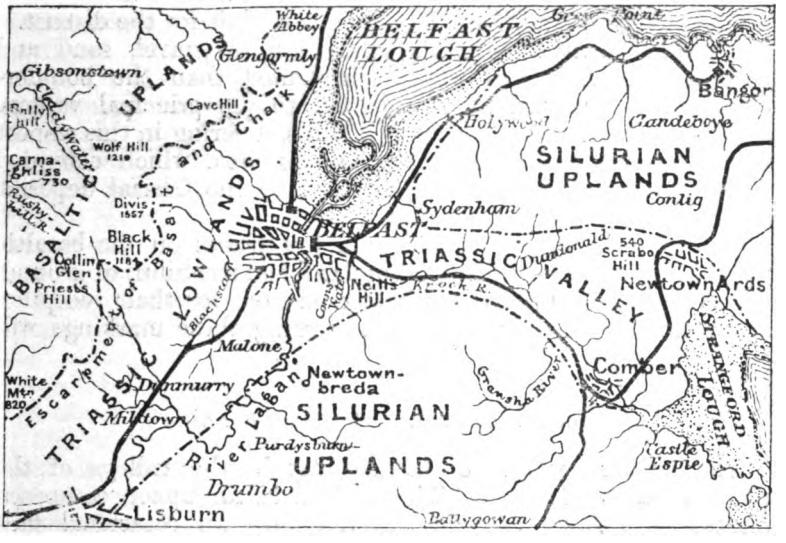
The most pronounced physical feature in the district is the bold and occasionally precipitous escarpment which marks the termination of the basaltic plateau, a region of high ground which slopes westward and attains its greatest elevation (Divis Mountain, 1567 feet) in a range of hills near the edge of the escarpment. The Upper Cretaceous and patches of Lower Jurassic rocks emerge only on the steep slopes of the escarpment, with a broader belt of Triassic marl below which causes the overlying rocks to break away in huge slips.

The central area of low ground is formed of the Triassic marls and sandstone, more or less deeply covered with drift. This Drift extends towards the east and south-east, and effectually conceals the junction between the Trias and Silurian, thus rendering the boundary between the central valley and the Silurian Uplands less marked than that between the former and the Basaltic Uplands.

FIG. 5.

INDEX TO BELFAST SHEET.




No part of the district is free from glacially transported materials, though these are very unequally distributed, being accumulated to a great depth in some places and in others merely sprinkled thinly in hollows among uneven surfaces of bare rock; and they also vary greatly in composition in different parts of the district. Mr. Lamplugh.

The most usual form of this glacial drift is a tough unstratified boulder-clay in which the included stones are chiefly of basalt, chalk and sandstone in the country west of the Lagan, and of the same with a preponderating addition of slate fragments in the

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Mr. Lamplugh

country east of that river. Where unweathered this clay is often calcareous, but not in the same degree as the richly calcareous boulder clays of the Dublin district mentioned in last year's report. Besides these local materials, the boulder-clay usually contains a few stones of distant origin, such as quartzite, gneiss, granite, etc., probably transported from North Antrim, and riebeckite-rock like that of Ailsa Craig. These boulders always indicate a transport in a southerly direction. Much information regarding these far-transported boulders has been placed on record by members of the Belfast Naturalists' Field Club, and will be drawn upon in compiling the memoir. Fragmentary marine shells have also been obtained from these clays at several localities, but are usually rare. The best collections were made many years ago when excavations for the waterworks reservoirs on the Antrim Road were in progress; these are fortunately preserved in the Museum of the Belfast Natural History and Philosophical Society, and have been carefully worked out and added to by Mr. S. A. Stewart. Foraminifera also occur in these drifts, and have been closely studied by Mr. J. Wright of Belfast. As noted below, shell fragments have been found during our survey at points farther inland than the previous records for the district.

Stratified drift material, in the form of gravel, sand and laminated clay, is less widely distributed than the boulder-clay and is confined in this district to the principal valleys, and to the lower ground among the hills, differing in this respect from the stratified drift of the Dublin area, which extended upward to the highest levels attained by the Glacial deposits, as described in last year's report.

Glacial striæ were observed at a few places on the basaltic upland, but were found most abundantly on the Silurian ground, where the rock-surfaces are better adapted for their reception and preservation. Some details regarding these markings will be given subsequently.

## DRIFTS OF THE BASALTIC UPLAND.

Mr. Wright.

The deeper sections of boulder-clay in the valleys of the plateau nearly always exhibit two bands, an upper, composed almost entirely of basaltic material with an occasional flint or other foreign pebble, and a lower, which although largely basaltic, contains abundant chalk and has a highly calcareous matrix, the line of separation between these clays being usually fairly sharp. Either the one or the other of these divisions is, however, occasionally absent; and sometimes where both are present their junction is ill-defined. They sometimes include impersistent layers of stratified silt and sand. The only organisms hitherto recorded from these upland boulder clays are *Ostracoda*, *Foraminifera*, and fry of two *Mollusca*, found by Mr. J. Wright of Belfast in the washings of a boulder clay occurring at an altitude of 1300 feet on Divis Mountain, and at 800 feet on Wolf Hill. Shell fragments were, however, collected from the boulder clay farther westward

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during the mapping of the ground, including a broken valve of *Astarte sulcata* from a section in the bank of the Clady Water near Gibsonstown, and a fragment of the same species from a section of chalky boulder-clay in the Rushyhill River, about five miles farther southward. Mr. Wright.

The same association of shell-fragments with the Ailsa Craig rock which was commented on last year in the Dublin district was again observed during the present year's work. Thus, pebbles of this rock were abundant in many places on the plateau, and were found up to an altitude of 875 feet above O.D. in sections three-quarters of a mile east of Priest's Hill. Mr. Muff.

Fragments of the same rock were also noticed at the surface on the northern slope of White Mountain; and, like the flints, which are often abundant in the soil of the upland where the basalt now lies immediately beneath the surface, such travelled fragments probably indicate the former existence of a thin drift-covering which has been removed by denudation. Mr. Kilroe.

The boulder-clay of the plateau usually forms smooth gentle slopes and is rarely heaped up into the drumlins which are so prevalent in other parts of the district. Two well-marked drumlins were, however, observed on the upland north of White Mountain, with axes trending approximately E. 20° S.

Irregular mounds of gravelly drift, due to the action of water in assorting materials of similar character to those which form the boulder-clay, are strewn along several of the valleys which carry the drainage of the plateau westward to Lough Neagh. These mounds cluster more thickly and are also larger and steeper along the courses of the streams, often occurring in the angle between two confluent streams. Mr. Wright.

These features are especially well-marked in the valley of the Clady Water. In this district there are also traces of the action of glacial flood-waters in the form of several steep-sided valleys cut across the subsidiary water-sheds through the basalt and its drift-covering.

One of these valleys, about 35 feet deep, crosses the water-shed between Carnaghliss and Ballyhill, serving now only to carry off the drainage of a small bog. A gravelly deposit in the Clady Water depression corresponds in level with this channel and has the characteristic flat top, steep sides, and well-marked current bedding of a delta. This delta may have been formed by the Clady Water and a tributary stream when entering a glacial lake whose overflow was through the above mentioned channel.

At a later period, a portion of the valley near Gibsontown appears to have been flooded owing to the presence of a barrier of drift athwart the depression, so that a small lake was formed which probably persisted into post-glacial times, until the stream which flowed from it had sunk its channel through the barrier. This episode is marked by a series of laminated clays resting on the boulder clay and covered by later flood-gravels.

Mr. Wright observed four examples of glaciated surfaces on the basalt, the direction of the striæ reading between E. 17 S.

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Mr. Wright. and E. 37 S., with cross-striæ in one case, under the shelter of a small boss, reading E. 45 N.—W. 45 S. Mr. Kilroe also found striæ in two places on the basaltic upland which indicated a south-easterly movement of the glaciating agent.

The upper slopes of the escarpment are usually too steep to permit the drift to lodge, except here and there in narrow strips; but in the lower gaps where the escarpment recedes or is trenched by valleys, as in Collin Glen and at Glengormly, the boulder-clay clothes the slopes and extends over the summit. Some of the slips under the steeper portions of the escarpment appear to be preglacial, as the boulder-clay sweeps smoothly over them; others however are later than the deposition of the clay.

### DRIFTS OF THE TRIASSIC LOWLANDS.

The slopes of Triassic marl at the foot of the escarpment of basalt and chalk are overspread with tough red boulder clay largely derived from the underlying marl, and north of Belfast no other drift is found between the escarpment and the shores of the Lough. But in the lower part of the depression, along the course of the river Lagan, great masses of stratified drift, in the form of gravel,s and and laminated 'warp'-clay, are encountered, and are sometimes predominant over the boulder clay. The investigations have not at present included enough of the valley to enable the southward limits of these deposits to be determined, and until this is done, some uncertainty will
Mr. Kilroe. remain in regard to them; but there can be no doubt that they represent water-borne sediments, derived from the same source as the materials of the boulder-clay. These deposits enter the district on the south near Lisburn in an irregular band about three miles in width, fringing the Lagan on both sides, but contracting somewhat suddenly northward. They nearly always rest upon boulder-clay, and in the northward part of their course are also sometimes overlain by boulder-clay of a more marly character and containing less chalk than that below. To the westward of Lisburn, and between that place and Dunmurry, a series of conspicuous mounds and ridges of gravel showing the characteristic esker-structure may be observed. It was originally believed that these ridges formed a single esker-train which ran eastward to Lisburn and thence north-eastward to Dunmurry, but Mr. Kilroe is of opinion that two distinct eskers are represented, one of which, running south-west from Dunmurry, terminates in a delta-fan of sand near Lisburn, while the other, starting near Milltown, goes south-westward and terminates similarly at Redhill, beyond the western boundary of the present map. Another delta-like spread of sand which occurs three-quarters of a mile W. by S. of Lisburn, is believed to mark a later stage when the waters which formed the last-mentioned esker broke away from their channel at this point. Sections in these esker-gravels sometimes show well-marked faulting on a small scale.

Besides these esker-ridges and mounds with their characteristic arched-bedding, the stratified drifts are spread out in more or

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less horizontally-bedded sheets which in the southern part of the district consist largely of gravel, but become more sandy northward, until finally, north of Malone, they contain no gravel, and are composed entirely of fine loamy sand with thin seams of laminated red clay or warp. It is suggested that these deposits were laid down in a temporary lake which occupied the valley when Belfast Lough was blocked with ice. Further evidence for the existence of this lake is found in the presence of gravelly deposits along the slopes of the Silurian hills to the eastward of the valley, forming fringing banks and rude terraces, at a height of about 165 feet above O. D. These gravels are most conspicuous in the neighbourhood of stream-channels descending from the high ground. They appear to indicate the arrest of the burden of these streams, and its arrangement at the margin of the old lake. The highest part of the lowland sands is however about 20 feet higher than the level of these gravels. Mr. Kilroe.

The broad low ridge on the southern side of Belfast, which separates off a portion of the old Lagan valley into a subsidiary basin now drained (and sometimes flooded) by the Blackstaff stream, is principally composed of loamy stratified sands, in places not less than 50 feet thick, which are the direct prolongation of the stratified drifts above described. These sands are over-lapped on both flanks of the ridge by red marly boulder-clay which becomes broken into patches and thins out on the upper slopes of the ridge. At their base the sands pass into a few feet of finely laminated silty clay or 'warp' which is frequently rippled-marked, and they appear also to fade off laterally into similar material, thus forming a huge lenticle resting upon and partly covered by boulder clay. This lenticular arrangement seems to be in part due to original inequality of deposition and in part to the erosion of the stratified mass during the deposition of the upper boulder-clay. Mr. Lamplugh.

The sands expand again on the eastern side of the Lagan, and are well displayed in the south-eastern suburbs of Belfast between Newtownbreda and Ormeau Park; and it is probably the same series which reappears to the northward of the clayey low ground drained by the Conn's Water, and forms the much-dissected sandy terrace extending along the eastern side of Belfast Lough to Holywood. Along the inner margin of this terrace, where it is dominated by steep hill-sides of Silurian rock, the material again becomes gravelly; and on the southern outskirts of Holywood there is an irregular mass of gravel which probably represents the delta-deposit from a small 'dry gap' on the adjacent hill-slope. This 'dry gap' is a short ravine crossing the narrow spur of slate-rock which bounds Holywood Glen on the west; it may be explained as the 'overflow channel' of waters which were impounded in the Glen and escaped westward into the Belfast basin.

The only organisms that have been detected in the stratified drifts above described are foraminifera, found very sparsely in the sands of South Belfast by Mr. J. Wright.

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## DRIFTS OF THE DUNDONALD VALLEY.

Mr. Lamplugh. The Pre-Triassic depression, now lined with Triassic sandstones, which runs from the head of Belfast Lough to the head of Strangford Lough, contains a complex drift series, in part stratified and in part unstratified. At the wide entrance to the valley, east of Belfast, the loamy sands already described are largely replaced by gravels, which at Neill's Hill are intercalated with bands of boulder-clay, as described by Miss S. M. Thompson (Madame Christen).* At this place both the gravel and the boulder clay have yielded shell-fragments.

Mr. Muff. The gravels are continued thence into the valley at Dundonald in moundy esker-like features, but farther eastward they contract into rude much-dissected terraces lining the boulder-clay slopes of an irregular inner valley. The arrangement of these deposits Mr. Seymour. implies that they were the product of an outflow of water from the westward into Strangford Lough. Around the head of the Lough, north and north-east of Comber there is a low-lying tract of about 2 square miles of sand, which appears to represent the delta-fan formed at the same period. Some oval tracts of boulder-clay rising above this sand-plain are evidently the tops of half-buried drumlins. Patches of sand and gravel also occur here and there along the eastern shore of the Lough as far as the operations of the Survey have been extended. At Castle Espie, overlying the small patch of Carboniferous Limestone, part of the drift is composed of loamy sand and stones, the material being unstratified and the stones scattered just as in a boulder-clay, although the matrix is mainly sand derived from the Triassic Sandstones.

Mr. Muff. On the opposite side of the Lough, around Newtown Ards, there is a discontinuous strip of gravel banked against the foot of the hills, which is composed principally of Silurian débris. It has probably been accumulated as the delta of flood-waters passing through the hollow in the hills between Bangor and Newtown Ards, as disconnected patches of moundy gravel occur along nearly the whole course of this hollow.

## DRIFTS OF THE SILURIAN UPLANDS.

Mr. McHenry The drift of the hilly Silurian ground between the sea and the Dundonald valley consists almost entirely of boulder-clay, which, for the most part, is heaped up into steep-sided oval hills or "drumlins." These are set thickly over the district, and give it the curious hummocky appearance referred to in the homely simile sometimes applied to Co. Down—that it is the "basket-of-eggs county." Save for a few high ridges of bare slate, these drumlins form the most prominent features among the hills, and it is often only in the hollows between them that rock is revealed. The boulder-clay in these drumlins is frequently known to be 40 feet or more in thickness; and in ravines bordering the Dundonald valley it is seen to attain a thickness of

*Proc. Belfast Naturalists' Field Club*, 1893-94, pp. 122-123.

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at least 80 feet. Although the drumlins are perhaps rarely actually moulded upon rock-bosses, their distribution seems to indicate that they are in some manner caused by the unevenness of the rocky floor, as it is mainly in districts where the rocks form an irregularly broken surface that these hillocks of boulder-clay occur. Their comparative rarity on the basaltic upland, and their feeble development on the limestone plain near Dublin commented on in last year's report, may be thus explained. As was pointed out by Rev. M. H. Close, the longer axes of these mounds usually coincide in direction with the trend of the glacial striæ. Mr. McHenry

Glaciated rock-surfaces are of common occurrence throughout the Silurian ground. In the district under consideration, their general trend is towards S.S.W. in the vicinity of the Lagan valley, and due S. on the high ground farther eastward, but with local deviations in the direction of Strangford Lough on the lower slopes.

The glacial phenomena of the Silurian hilly ground south of the Dundonald Valley are very similar to those of the district above described, except that in several places in the valleys there is a local development of gravelly stratified drift. Drumlins of boulder-clay are abundant, and the outcrops of slate-rock occur principally in hollows between them. These drumlins have frequently obstructed the pre-glacial drainage-channels, forcing the present streams into tortuous new courses, in part following the old hollows, and in part breaking away from them in steep-walled rocky gorges. Thus the Gransha River, which describes three sides of a rectangle, passes through three or four late-glacial or post-glacial rock-channels before it reaches the Comber valley. Gravels, composed mainly of the local slate and grit, but with a fair sprinkling of far-travelled rocks like those in the adjacent boulder-clays, and with an admixture of yellow sand, occur in several of the wider valleys in the form of flat-topped mounds abutting upon the lower slopes. Mr. Seymour.

The same features extend southward into the ground at the margin of the map surveyed by Mr. Muff, and eastward up to the Lagan valley through an area examined by Mr. Kilroe. On the slopes in the neighbourhood of the main valley, however, the boulder-clay becomes more markedly calcareous and contains many fragments of chalk. In clay of this character Mr. Kilroe has detected shell-fragments in three hitherto unrecorded localities along the course of the Purdysburn and its feeders. Mr. Muff. Mr. Kilroe.

The prevalent striæ on the hills between the Lagan valley and Strangford Lough are directed to points between S. and S.S.E.; but in a few places cross-striations were observed having an approximately E.–W. direction which are believed by Mr. Kilroe to indicate an earlier westward movement of the glaciating agent.

Mr. Lamplugh and his colleagues are of opinion that the facts above summarised are best explained by the land-ice theory. From this point of view the whole area was buried under Summary.



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Summary. an ice-sheet during the period of maximum glaciation. The general movement of this ice-sheet was southward and independent of the contours of the buried land in the district, though the steeper features appear to have caused local modifications in the direction of flow. During the dwindling of this sheet, which may not have been continuous and uninterrupted, the irregular gravels of the basaltic upland and of the Silurian hills were formed by floods due to the melting of the ice, while the fine sands and warps of the Lagan valley were deposited in temporary lakes held up by the ice, and the esker-gravels mark the river-courses with which the ice was channelled.

## POST-GLACIAL AND RECENT DEPOSITS.

Mr. Lamplugh. With the exception of the estuarine clays of Belfast Lough and Strangford Lough, the post-glacial deposits of the district are scanty and unimportant. The valley of the Lagan is too narrow and too deeply trenched through the drifts to permit much development of river-gravel terraces. Owing to its present sluggish course, however, its low alluvial flat is rather extensive in places. The other streams are small, and generally descend from the hills in deep gorges, around the mouths of which there is frequently a fan-shaped sheet of stony wash.

The estuarine clays were thoroughly studied by Mr. R. Lloyd Praeger when good sections were available during the construction of docks, etc.; and the work of the Survey in these deposits has been confined to the mapping of the boundaries. The "25-ft." Raised Beach, which constituted the shore-line during part of this period, is represented in one form or another throughout the coast-line of the district.

## ECONOMICS.

Bricks of local manufacture furnish the chief building material for Belfast, and owing to the rapid growth of the city the demand for these has been great. Extensive brick works, fitted with modern appliances, have been established in large numbers around its outskirts, and are now sufficient not only to supply the local demand but to yield a large surplus output which is sent to other parts of Ireland. In some of these works the raw material is derived entirely from the boulder-clay, or with an admixture of the stratified 'warp' clays where these are also present; but some of the largest yards are worked deeply in the Triassic marl, though here also the boulder-clay is used where it occurs as a capping to the marl.

The glacial sands are extensively dug for building purposes and in some places for use as moulding sands. The gravels are employed for the usual purposes through the district.

The estuarine clay, locally known as "sleech," on which the central part of Belfast is built, is too soft to make a safe foundation for heavy edifices; and much expense is therefore entailed in preparing a firm platform by driving in long timber piles before building is begun in this tract.

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Small patches of peat occur here and there in hollows among the Silurian hills, and there are wider tracts of no great thickness on the higher part of the basaltic upland. Numerous places were also noticed where it had once existed but had been cut away for fuel. Mr. Lamplugh.

## AGRICULTURAL NOTES.

From the great variety which obtains amongst the superficial deposits in this area may be inferred a corresponding variety amongst its soils and subsoils. Commencing with those formed of boulder-clay on each side of the valley a strong contrast is noticeable between the boulder-clay soils formed upon the basalt plateau and along the eastern slope of the escarpment and those partially clothing the Silurian hills. The basalt from which the former boulder-clay has been derived has usually weathered to such an extent as to yield a stiff, retentive, cold soil, mostly under pasture, but, where drainage and liming are lacking bearing a poor herbage, including rushes, 'sprits', *Ranunculus*, *Pedicularis palustris*, and other weeds. The valuable constituents which weathering basalt imparts are overridden by the physical nature of the soil; but with drainage and liming the land is made to wear a more propitious aspect. The good quality of basaltic soils is to be seen in the parts where the rock covering is thin and the subsoil rubbly, and where in consequence the percolation is free. These are the portions selected for tillage near the summit of the escarpment. Mr. Kilroe.

The cultivation over the Silurian ground on the east side is of an advanced type; the soils and subsoils being characteristically stony, in many places even rubbly, so that the labour of tillage is comparatively small. The fine material makes a favourable seed bed, and a good receptacle for manures, and the district is favourably situated near a large centre of population for artificial treatment. The soils are probably greatly wanting in the three main constituents—lime, potash, and phosphoric acid—in available form at least, and for crops they require "full manuring."

The marly boulder-clays of the valley as well as some warp-clays interstratified with the sands, containing few stones and usually little sand, form highly retentive soils and to a large extent are under grass. The grass forms a strong thick coat, but in many places rushes appear in abundance. Some of the warp clays contain sand and form soils not difficult to till and of high quality. The more retentive warp-clays and the marly boulder clay contain carbonate of lime sometimes in large quantity, though the uppermost layer, including the soil and immediate subsoil, has become decalcified. A shallow-rooting herbage therefore cannot derive much direct advantage from these supplies, and capillary attraction which would otherwise place this valuable constituent within easy reach of the roots, is sluggish in these highly retentive clays, and in consequence fulfils its functions but feebly.



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Mr Kilroe.

The gravelly boulder-clay here and there met with along the lowest part of the valley from Ballymacoss, eastward by Lisburn, forms soils well suited to tillage, but generally more under pasture than tillage. The herbage borne is of good quality, and with fair treatment these soils form excellent land. In this division we may include the sheep-walks east of Purdie's Burn, the exceptionally good land south of Dunmurry, and the grazing farms north and north-west of Lisburn.

Sands bordering the Lagan river are much availed of for market-gardening, both south-west and north-east of Lisburn. They yield themselves to tillage at the minimum of cost, form dry soils for early cultivation, and with good management can yield two crops yearly. They present a curious diversity when laid down, some bearing a good thick coat of perennial gramineous herbage, while others lose their hold on grass, and require to be kept in rotation cropping.

## IV.—MAPS AND MEMOIRS PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year:—

### A. ENGLAND AND WALES.

#### I.—MAPS.

*One-inch Maps (New Series.)*

Sheet 123 (Stoke-up-Trent). Two editions with and without Drift. By W. Gibson, T. I. Pocock, and C. B. Wedd.

Sheet 314 (Ringwood). One edition with Drift. By C. Reid, F. J. Bennett, and E. E. L. Dixon.

The following One-inch New Series Maps, previously issued hand-coloured, have been replaced by Colour-printed Maps:—

Sheets 232 and 248 (with and without Drift).
„ 249 (without Drift).

The following One-inch New Series Maps have been colour-printed, and await the publication of accompanying Memoirs.

Sheets 298 and 317.

*Six-inch Reference Maps.*

One hundred and thirty-nine manuscript coloured copies of six-inch sheets and quarter sheets have been made from the field copies, and deposited in the office for public reference. These are as follows:—

Carmarthenshire.—41 S.E.; 42 S.W.; 49 N.W., N.E., S.W., S.E.
Cheshire.—35 N.E., S.E.; 36, 37 N.W., S.W.; 42 N.W., N.E., S.W., S.E.; 43 N.E., S.W.; 44 N.W.; 49 N.W., N.E., S.W., S.E.; 50 N.W., S.W., S.E.; 51 N.W.; 56 N.E.; 57 N.W.; 62 S.W., S.E.
Cornwall.—35 N.E., SE.; 36 N.W., N.E., S.W., S.E.; 37 N.W., S.W.; 43 N.E., S.E.; 44 N.W., N.E., S.W., S.E.; 52 N.E., SE.; 53 N.W., N.E., S.W.; 62 N.W., NE.; 65 N.W., N.E. S.W., S.E.; 71 N.E., S.E.; 72 N.W., N.E., S.W., S.E.

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Derbyshire.—54 N.W., N.E., S.W., S.E.; 55 N.W., N.E., S.W., S.E.; 56 N.W., N.E., S.W., S.E.
Glamorganshire.—14 S.E.; 22 N.E.; 23 N.W., N.E.
Hampshire.—36.
London.—1 S.E.; 3 S.E., N.E.
Middlesex.—14 N.E., S.E.
Nottinghamshire.—49 N.E., S.E.
Shropshire.—3 S.W., S.E.; 9 N.W., N.E.
Staffordshire.- 3 S.W.; 6 N.E., S.W., S.E.; 7 N.W., S.W., S.E.; 10 S.E.; 11 N.W., N.E., S.W., S.E.; 12 N.W., N.E., S.W., S.E.; 13 N.W., S.W., S.E.; 16 N.E., S.E.; 17 N.W., N.E., S.W., S.E.; 18 N.W., N.E., S.W., S.E.; 19 N.W., N.E., S.W., S.E.; 22 N.W., N.E., S.W., S.E.; 23 N.W., N.E.; 24 N.W., N.E. S.E.; 28 N.W., N.E., S.E.
Yorkshire.—4 N.W., N.E., S.W., S.E., 131.

### II.—MEMOIRS.

Summary of Progress of the Geological Survey of the United Kingdom for 1901, pp. 219. Price 1s.

The Water Supply of Berkshire. By the late J. H. BLAKE, with contributions by W. WHITAKER. pp. 115. Price 3s.

The Geology of the Country around Exeter. By W. A. E. USSHER, with Petrological Notes by J. J. H. TEALL. pp. 122. Price 2s

The Geology of the Country around Southampton. By C. REID, with contributions by W. WHITAKER. pp. 70. Price 1s. 6d.

The Geology of the Country around Ringwood. By C. REID, with contributions by F. J. BENNETT and E. E. L. DIXON. pp. 62. Price 1s.

The Geology of the Country around Stoke-upon-Trent. By W. GIBSON and C. B. WEDD. pp. 87. Price 1s. 6d.

The Geology of the South Wales Coalfield. Part 3. The Country around Cardiff. By A. STRAHAN and T. C. CANTRILL. pp. 147. Price 2s. 3d.

## B. SCOTLAND.

### I.—MEMOIRS.

The Geology of Eastern Fife. By SIR ARCHIBALD GEIKIE, with Appendix of Fossils by B. N. PEACH, pp. 421. Price 8s.

The Geology of Lower Strathspey. By L. W. HINXMAN and J. S. GRANT WILSON, with Petrological Notes by J. S. FLETT. pp. 91. Price 1s. 6d.

## C. IRELAND.

### I.—MAPS.

*One-inch Maps.*

Revised editions of the following one-inch maps of the Geological Survey of Ireland were issued, the revision-work being generally confined to the Silurian rocks:—

Sheets 36, 48, 49, 58, 59, 60, 68, 69, 70, 71, 72, 78, 81, 82, 91, 92, 101, 102, 111, 112, 120, 121, 124, 128, 129, 130, 133, 138, 139, 144, 145, 147, 148, 149, 154, 156, 157, 158, 159, 165, 167, 168, 169, 178, 179, 180.

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*Six-inch Reference Maps.*

Twelve manuscript copies of six-inch sheets have been made from the recently completed drift maps of the Dublin area, and are now available for reference in the office :—

Co. DUBLIN. 14, 15, 16, 17, 18, 19, 22, 23, and 25.

## *LIST OF EXTRA OFFICIAL PUBLICATIONS.*

ANDERSON, Dr. T. and FLETT, Dr. J. S.—Preliminary Report on the Recent Eruption of the Soufrière in St. Vincent, and of a visit to Mont Pelée, in Martinique. *Proc. Royal Soc.* vol. lxx. pp. 423-445.

HILL, J. B.—The plutonic and other intrusive rocks of West Cornwall in their relation to the mineral ores. *Trans. Roy. Geol. Soc. of Cornwall.* vol. xii. p. 546.

NEWTON, E. T.—*Trogontherium* from a Pleistocene Deposit in the Thames Valley. *Geol. Mag.* Dec. iv., vol. ix. p. 385.

REID, C. — Note on the Plant-remains of Roman Silchester. *Archaeologia.* vol. lviii.

STRAHAN, A. — On the origin of the River System of South Wales, and its connection with that of the Severn and the Thames. *Quart. Journ. Geol. Soc.*, vol. lviii. p. 207.

THOMAS, H. H—The mineralogical constitution of the finer material of the Bunter Pebble-Bed in the west of England. *Quart. Journ. Geol. Soc.* vol. lviii., p. 620.

WOODWARD. H B.—Further Note on the Westleton Beds. *Geol. Mag.* Dec. iv. vol. ix., pp. 27-30 ; *Rep. Brit. Assoc.*, for 1901, p. 635.

————.—Some Railway Cuttings in Suffolk. *Geol. Mag.*, Dec. iv., vol. ix., pp. 129-132.

————.—Note on the occurrence of Bagshot Beds at Combe Pyne, near Lyme Regis. *Ibid.*, pp. 515, 516.

# APPENDIX.

## I. ON THE DEVELOPMENT OF CRYSTALLINE SCHISTS FROM GRANITE AND HORNFELS IN ZONES OF SECONDARY SHEARING.

BY C. T. CLOUGH, M.A.

In the course of the survey of central Ross-shire during last season, important evidence was obtained of the development of planes of schistosity by thrust movements in the granitic rock of that region and in the sedimentary strata which have been hornfelsed by that igneous mass and its apophyses.

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Near a hill called Cnoc an t' Saic, which lies about two miles S.E. of the Post Office of Craigs, and about seven miles W.S.W. of Bonar Bridge, Ross-shire, there are good exposures of the augen-gneiss which has been frequently referred to in previous issues of the Summary of Progress. In some localities the augen-gneiss is represented by a granitic rock which shows no distinct foliation, containing phenocrysts of beautifully zoned felspar with indications of idiomorphic outlines. The rocks of sedimentary origin appear, in places, either as knotted hornfels or slightly schistose beds. In these localities various thrust planes have been detected, near which the rocks become sharply twisted, attenuated and deformed: indeed, the phenomena are in many respects the counterpart of those near the Pre-Torridon thrusts of west Sutherland. The hornfels near these thrusts becomes converted into mica-schists, and the granitic rocks are changed into finely foliated augen-gneisses with a granulitic matrix.

Some of the schists resulting from the deformation of the hornfels closely resemble Moine Schists found miles away from the augen-gneiss. Indeed the folding and alteration which have taken place since the intrusion of the granite seem competent to have produced the different types of schist now generally found in the Moine Series. At the same time it must be admitted that in other sections we see phenomena which suggest that the sediments may have been to some extent schistose before the solidification of the granitic rock took place.

The hornfelsed rocks, the chief areas of which are shown in the accompanying map, must originally have been muddy sediments with thin sandy laminæ closely resembling those near Kildermorie.* Where the hornfelsed character is most pronounced, they are extremely tough, hardly break along the bedding-planes and frequently contain crowds of small dark grey or pale grey spots, together with small pink garnets and thin streaks of pyrites. In those places where the spots are spherical there is nothing to show that the beds have ever been folded and the angle of dip is generally small. From rocks of this type there are gradations to others, more micaceous and schistose, containing garnets with rounded edges, and spots which are flattened and elongated in one direction, which, in places, crosses the bedding planes at a considerable angle. From the shape of the spots it is inferred that these schistose rocks were once in a hornfelsed condition, and have subsequently been exposed to movements which have rendered them schistose. As regards the hornfelsed rocks, in the special area now under consideration, it is doubtful whether any were in a schistose condition before the intrusion of the granitic rock.†

* For a description of these by Dr. Crampton and Dr. Flett see Summary of Progress for 1901, p. 101.

† See also Mr. Peach's observations in the Summary of Progress for 1898, p. 9.

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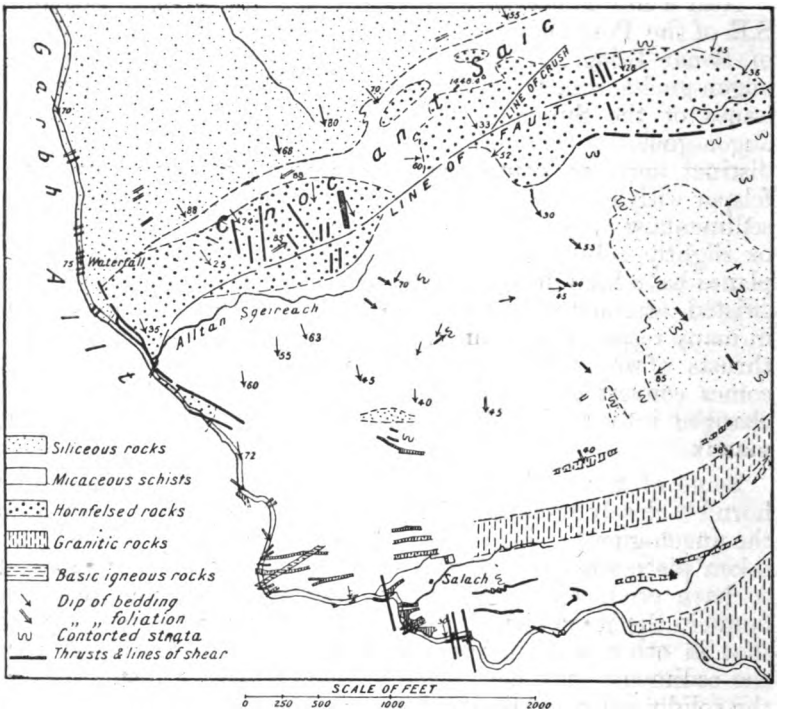


Fig. 6. *Map of country near Cnoc an t' Saic, S.W. of Bonar Bridge.*

One set of thrusts, nearly vertical and striking N.N.W. is seen on the S.E. side of Cnoc an t' Saic. (See Map). Other thrusts, almost horizontal, cross the N.E. bank of Garbh Allt rather more than half a mile S.W. of the top of Cnoc an t' Saic. Other lines of thrust striking E.N.E. probably also occur, but they are not seen in clear sections. On Cnoc an t' Saic the most distinctly hornfelsed rocks form a narrow band extending W.S.W. and E.N.E. the general dip being S.S.E. at an angle of about 25°. Thin strips of schistose rock, produced by the thrust movements, cross this belt in a N.N.W. direction.

The vertical thrusts striking N.N.W. are also well seen in Garbh Allt, where they affect both the sediments and the thin sheets of granitic rock. In the accompanying diagram (Fig. 7) the vertical thrust traverses micaceous schist, the latter being shown on left side of drawing. Away from the thrust the strike of the schist is about E.N.E., but on approaching it the bedding planes become nearly vertical and are much attenuated. In the line of the thrust the sharp folds in the schist are faintly visible, and new planes of schistosity are developed parallel to the plane of vertical movement and the axial planes of the folds. The newer schistosity almost effaces the original planes of bedding.

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On the N.W. and S.E. sides of the band of hornfels on Cnoc an t' Saic just referred to, there are schistose rocks, generally dipping S.S.E., like most of the members of the Moine Series of the neighbourhood. The schists on the S.E. side show indications in places of having once been in a hornfelsed condition, but their knots or spots are now often deformed. Both the N.W. and S.E. boundaries of the band on Cnoc an t' Saic are tolerably sharp, and they appear to represent lines of contortion accompanied in places with thrusting. The movements which gave the E.N.E. strike are of special interest, as this is the most common strike of the Moine schists over a large district. In the schists on the N.W. and S.E. sides of the hornfelsed band of Cnoc an t' Saic no thrusts striking N.N.W. are seen, but in some places the strike suddenly twists into a N.N.W. direction. It seems probable, therefore, that the movements which produced the N.N.W. strike and the N.N.W. thrusts are of the same age, and later than those which gave rise to the E.N.E. strike, —the latter being the general strike of the Moine schists of the district.

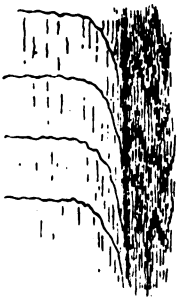

DIAGRAM SECTION OF VERTICAL THRUST IN GARBH ALLT

FIG. 7.

It is probable, also, that the movements which produced the almost horizontal thrusts are later than those which gave rise to the E.N.E. strike. Near one of the thrusts in the Garbh Allt, the garnetiferous mica schist, a little S.E. of the section where the thrust is exposed, is thrown into folds with nearly horizontal axial planes, and it seems clear that the rock was already in the form of schist before such folding was developed. We know, too, that in various places far away from the augen-gneiss, there are almost horizontal planes of movement which cut both the bedding and foliation of the adjacent Moine schists at considerable angles; and that along these planes we see, in places, crumpled chlorite schist, no doubt representing an intrusive rock, in which the general direction of foliation is parallel to the plane of movement.

Nowhere in the area now being described are the most distinctly hornfelsed rocks seen in contact with the augen-gneiss; indeed they are often separated from it by schists in which the hornfelsed character is not observable. This may, perhaps, be explained on the supposition that near the edge of the intrusive rock there has been more differential movement since the period of hornfelsing than further off.

The rocks of sedimentary origin which are in contact with the granitic rock are not all equally schistose; some are but slightly so and contain small spots of biotite. Where the latter are in contact with it, the granitic rock is also less foliated than usual, or even free from foliation. Both the less schistose Moine

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rocks and the bands of granitic rock in contact with them are in the Garbh Allt, crossed by vertical thrusts striking N.N.W., and along these thrusts both the Moine sediments and the intrusive rock become very micaceous and schistose. It is clear, therefore, that at all events in some parts of the granitic rock the foliation or schistosity is secondary, and due to the causes which produced, or intensified, the schistosity in the altered sediments.

Various other phenomena agree with this conclusion. On Carn Salach,—a hill about a mile and a half S.E. of Cnoc an t' Saic,—within the augen-gneiss various thin strings of fine grained pink rather acid rock occur, in which the foliation planes make an angle with the margins, and continue outside these margins, to form the common foliation planes of the augen-gneiss.

On the north side of the pass N.N.W. of Carn Salach, thin strings of augen-gneiss are mixed with Moine schists, and both have been folded into isoclines with nearly vertical limbs. The Moine schists and granitic rock are very micaceous, finely schistose, and granulitic. The former contain much white mica, perhaps produced from felspar during the shearing process. In one thin strip the planes of foliation or schistosity cross the margin clearly, and are parallel to the axial plane of fold and the corresponding planes in the Moine schist. At other localities, for instance in the Garbh Allt, bands of granitic rock appear which are crossed by foliation planes making considerable angles with their margins, and in some instances parallel secondary foliation planes are also visible in the adjacent Moine schists.

In the places just referred to, the first foliation planes in the Moine schists are not highly developed, but they do exist, and it is a little doubtful in some cases whether any planes corresponding to them occur in the intrusive rock, so that the appearances suggest that the sediments may have been to some extent schistose before the intrusion took place.

This is also suggested by the occurrence of various granitic intrusions, with blue quartz blebs and no distinct foliation, in garnetiferous mica schist in the Garbh Allt, rather more than half a mile S.S.W., of the top of Cnoc an t' Saic. It is possible, however, that the intrusive rock may have continued in a liquid state for a very long period, and that during this time the sediments were in places folded and made schistose.

## II. Note on some Brecciated Stanniferous Veinstones from Cornwall.

By JOHN S. FLETT, M.A., D.Sc.

In connection with the work of the Geological Survey in Cornwall, which involves an investigation of the tin-lodes of that area, Mr. Donald A. Macalister has, at the request of the Director, collected a series of specimens of the tin-bearing veinstones, which have been sliced and subjected to microscopic examination.

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The material was obtained from four different mines, viz.—Dolcoath, Wheal Basset, South Crofty and Carn Brea; and Mr. John Scrivenor has obtained tin-ores from two others, viz.—Wheal Kitty and West Kitty; the results of his examination of these specimens are included in this note.

The veinstones differ a good deal both in appearance and in composition, but many of them are hard, splintery, dark-blue or dark-green, fine grained rocks, in which the brown colour and somewhat resinous lustre of fine granular disseminated tinstone can be observed, and in some cases the splendent faces of well developed crystals are visible on the surface of the hand specimens.

Some of these veinstones are typical breccias,* easily recognised as such by the naked eye, and contain angular or sub-angular fragments of white milky quartz, embedded in a matrix which is fine-grained and dark green or bluish-green in colour. This dark matrix is known to the miners as "peach," and, while in some cases it is so fine as to be cryptocrystalline in appearance, in others it is visibly composed of little acicular needles.

Others of these breccias are difficult to recognise at first glance, though essentially similar in structure to those just described, for the quartz fragments may be small, clear and transparent, and from the dark colour of the matrix and its abundance, they are very inconspicuous. Microscopic examination, however, leaves no room for doubt regarding their nature.

The matrix also, in which the quartz fragments lie, is very often itself a breccia in which broken masses of the dark, splintery "peach" are held together by a substance which closely resembles the fragments, but differs from them slightly in colour or in coarseness of grain.

Veins of white quartz frequently cross the brecciated veinstones at all angles, and these occasionally contain copper-pyrites. Tinstone does not occur in these latest veins.

It will be seen that the structure of the hand specimens indicates a complex history for these veinstones. They have apparently been produced by repeated processes of infiltration by mineral solutions, alternating with periods during which movement has taken place along the walls of the vein, and in

*That many of the tin lodes of Cornwall are brecciated is a fact which has long been known and has attracted a good deal of attention. Descriptions of individual cases will be found in the following papers among many others :—

Notes on New Rosewarne Mine. By C. Le Neve Foster. *Trans. Miners' Assoc., Devon and Cornwall*, 1866, p. 26.

On some Cornish Tin-stones and Tin-capels. By J. H. Collins. *Min. Mag.* Vol. iv., p.l. 1880.

Remarks on some Tin Lodes in the St. Agnes District. By C. Le Neve Foster. *Trans. Roy. Geol. Soc. Cornwall*, Vol. ix., Pt. iii. 1877.

The Lode at Wheal Mary Ann. By C. Le Neve Foster. *Ibid.* Vol. ix. p. 156, 1878.

Observations on the Rich Parts of the Lodes of Cornwall. By L. Moissenet, translated by J. H. Collins. 1877.

On the Metalliferous Deposits of Cornwall and Devon. By W. J. Henwood. *Trans. Roy. Geol. Soc. Cornwall*, Vol. v. 1843.

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this way masses have been deposited in the fissure which have at a later period been broken up and re-cemented by a fresh deposit, to be again shattered by renewed movement, and finally again consolidated into a firm, coherent mass. The microscopic examination of the specimens entirely confirms this view.

*Microscopic Characters of the Veinstones.*

The essential constituents of these tin-ores are quartz, tourmaline, chlorite and tinstone. Fluorspar, pale micas, iron oxides, copper pyrites, kaolin(?) are present also, but not universally, and occasionally there are pieces of altered felspar, and fragments of granite or of slate. The foreign ingredients, however, have usually been decomposed or impregnated with new minerals by the agencies by which the fissures were infilled, and their original characters have been largely modified in consequence.

Dolcoath.—Three samples of the material which was being crushed at Dolcoath mine during June, 1902, were sliced and examined. They were all quartz tourmaline breccias containing grains and crystals of cassiterite. All came from the 375 fm. level, where the country rock is granite. Of these specimens two consisted of broken fragments of quartz embedded in a finer-grained matrix of quartz and tourmaline. The third contained many aggregates of pale mica which appear to be altered remains of felspar, no doubt derived from the country rock, and in this specimen the "peach" was green, owing to the abundance of finely divided chlorite, while tourmaline was present only in small quantity.

The quartz fragments of the breccia vary in diameter from one inch downwards, but are mostly very small; they are full of fluid enclosures with mobile bubbles, and may contain also small transparent, colourless, isotropic grains, which are apparently to be referred to fluorspar. These often show traces of cubical crystalline form. The quartz of the larger grains is shattered and broken, and, when viewed between crossed nicols, exhibits very often a perfect cataclastic structure, with undulatory extinction and all the characteristics which are produced by the breaking down of this mineral under severe pressures.

The quartz of the matrix or "peach" is finely granular, and there can be no doubt it has in large part resulted from the grinding up of the crystalline quartz which first filled the vein, and of which the larger fragments represent the less altered residuum. But it is also clear that after the shattering of the first material which entered, a fresh mineral deposit was laid down which healed up and firmly compacted the broken mass, and of the minerals introduced at this time quartz was one of the most important.

Tourmaline is the mineral next in abundance to quartz. It takes the form of large, rounded, fissured, often broken grains, which are usually brown in their centres and blue on their edges and cracks, and of minute narrow, elongated prisms, always blue in colour, scattered through the quartz of the matrix. These frequently show rhombohedral terminations and hexagonal transverse sections, but the larger grains and many of the smaller needles are without crystalline faces.*

The tinstone resembles the tourmaline in the manner of its occurrence but forms rounded grains and short double pyramids in place of the long needles of the former mineral. The chlorite is in small irregular scales, pale green and greenish yellow, distinctly dichroic, and yielding grey polarisation colours of the first order even in very thin sections. With it is associated a pale bleached mica. The chlorite occurs in the matrix with the tourmaline, and forms a dark green, fine-grained "peach" which differs from the tourmaline-bearing variety in its colour and in being so much softer that it is easily scratched with a knife when it is richest in chlorite.

*Figures and descriptions of the blue "peach" of the Dolcoath mine will be found in Mr. Collins's paper, "On some Cornish Tin-stones and Tin-capels." *Min. Mag.* Vol. iv. 1880.

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A study of the sections demonstrates that the history of this rock has been as follows: A fissure opened and was filled with crystalline quartz which seems to have been accompanied by tourmaline, tinstone and fluor-spar, as all these are to be found in the interior of fragments of this first quartz deposit; and as the tourmaline and tinstone are in large crystals quite different from those of the latter infiltration, there can be little doubt that they belong to this early period. Moreover in certain cases both tourmaline and tinstone are rounded and broken, in the same manner as the adjacent pieces of quartz. Fine needles of tourmaline lie scattered through the quartz, and while the large rough broken grains are always brown in colour, these needles are invariably blue. They may be in part of the same age as the quartz, but as they are always crowded together near the edges of the fragments, where they form a transition to the surrounding peach, which is filled with similar needles, it is likely that such tourmaline is to a large extent of later origin and belongs to the second period of mineral infiltration.

After the vein had been filled with a coarsely crystalline mass of tourmaline, quartz and tinstone, movement set in and the vein rock was crushed into fragments varying in size, embedded in a fine granular broken-down matrix of similar composition. The second period of infiltration ensued; the porous, granular, ground-up quartz between the fragments of the breccia was filled with radiate clustered needles of tourmaline, and recemented by fresh quartz to form a hard coherent rock. In this way the dark blue "peach" originated. Fluor-spar and tinstone were also introduced at this time, as they occur in the "peach" in such a way as to show that they accompanied the fine needles of blue tourmaline.

Apparently the material entering the fissure in these two periods was essentially similar in composition and left a deposit of the same minerals, though probably not in exactly the same proportions. The blue "peach" is very rich in tourmaline and contains less quartz than the older fragments of the breccia, which are in consequence much paler in colour than the matrix in which they lie. The first tourmaline was brown, the later tourmaline blue, and often the older crystals are surrounded by fringes of blue needles, which sometimes also line the cracks which were produced by the fracture of the larger brown masses during the epoch of earth movement which intervened between the periods of deposition.

The order in which the minerals crystallised was apparently the same in both cases. Tourmaline, tinstone and fluor-spar are always surrounded by quartz, which we may infer was the last mineral to be deposited. Only very rarely do we find that tinstone encloses tourmaline or *vice versa*, and both were probably early minerals and perhaps contemporaneous. The later solutions passing through the fissure may perhaps have been able at some time to attack the surface of the quartz fragments, as these not unfrequently seem corroded and rounded by some such process, but subsequently a fresh layer of quartz full of tourmaline needles was laid down upon their surfaces.

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The last stage in the history of the tourmaline quartz breccias of Dolcoath was the renewal of earth movement with consequent disrupture of the veinstones. Cracks were formed into which a third infiltration penetrated, but this time it consisted principally of quartz with little tourmaline, and formed pale quartzose veins which cut across the dark "peach" and are very distinct from it in appearance. These last veins contain no tinstone, so far as can be made out from the specimens collected, and their quartz is granular crystalline, and shows no trace of having been subjected to movement and granulitisation.

From Wheal Basset (Flat Lode, 240 fms.) Mr. Macalister obtained several specimens of tin ore which show all the essential features of that described from Dolcoath. Fragments of clear quartz lie in an abundant matrix of dark blue "peach" very rich in minute prisms of tourmaline and containing also grains and crystals of tinstone. This "peach" has itself been broken up and the mass recemented by a paler coloured and more quartzose material in which there is less tourmaline. Finally the reconsolidated veinstuff has again been fissured and narrow, white quartz veins in which tourmaline is not common have filled up the cracks.

We have in this case four periods of infiltration, separated from one another by three epochs in which the material deposited in the vein has been fractured and in some cases ground up by movement of the walls on one another, and the history of the infilling of this lode may be summarised as follows:—

I. Opening of the fissure.
II. Infiltration of quartz, tinstone and tourmaline.
III. Brecciation of the veinstuff by movement.
IV. Formation of the "peach" by infiltration of much fine blue tourmaline, with tinstone and quartz.
V. The "peach" was shattered by renewed earth movement.
VI. The broken mass was healed up by deposit of fine quartz with tourmaline and tinstone.
VII. Renewed formation of fissures, this time on a smaller scale and not attended by severe detrition of the materials filling the vein.
VIII. The fissures were filled with fine quartz almost free from tourmaline. Coppery pyrites occur in these last veins and may have been introduced along with the quartz. There is no evidence that tinstone was deposited at this period.

It will be seen that the minerals deposited in stages II., IV. and VI. are essentially the same, and there is no reason to believe that a very long time elapsed between them. Tourmaline was present in all stages and so also was quartz, but tinstone belongs to the early history of these veins and copper pyrites to the last. Movement had almost ceased when the latest quartz veins were formed, for they are never brecciated and granulitised like the earlier. The fissures must have opened after the consolidation of the granite of the walls, but there is much reason to believe that the veinstones are to be regarded as dating from a time when the granite mass had not yet completely cooled, and the fissures served as passages along which heated solutions derived from the granite were freely circulating.

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*Carn Brea.*—The specimens from Carn Brea tell much the same story. The "peach" which surrounds the fragments of the first quartz here also has been brecciated, and the pale quartz which healed up the shattered mass is full of large tinstone crystals (belonging to period VI.). This quartz contains little tourmaline, and the tinstone, which is perfectly idiomorphic, has been deposited first, the quartz at a somewhat later period sealing up the vein. There is no evidence from the samples that a still later series of movements, followed by infiltration (VII. and VIII.) have affected this vein.

In some of the veinstones chlorite accompanies or in large part replaces the dark blue tourmaline of the "peach." It is in pale green, pleochroic scales, usually arranged in radiate groups, is strongly dichroic, and has a high double refraction for this mineral. It is abundant in the specimens obtained from the South Crofty mine and occurs also in some of the tin ores from Dolcoath. What relation it bears to the tourmaline is not quite clear from the sections, but both are apparently primary, as there is no evidence that the chlorite has formed from the decomposition of any other mineral in the vein. Sometimes tourmaline and chlorite belong to the same period of infiltration, in other cases the chlorite belongs to one period, the tourmaline to another.

Pieces of the country rock, which in all the veins examined was granite, are present also and are invariably much altered and inpregnated with tourmaline and quartz. The felspar is often entirely converted into an aggregate of pale micaceous scales, which may be infiltrated with iron oxides. Pseudomorphs in quartz and tinstone after felspar are also to be found In other cases a very fine-grained aggregate which may be kaolin has been formed. The same solutions as introduced the tinstone evidently attacked the felspar, converting it into a variety of secondary products, and partly removed these, depositing quartz and cassiterite in their place.

From West Kitty and Wheal Kitty, in the St. Agnes district, Mr. John Scrivenor has obtained specimens of the tin-bearing veinstones, which he has examined under the microscope, and the following particulars regarding them are extracted from his notes. Brecciation of the walls of the fissure, which undoubtedly occurs in this district, is not well shown in the slides. The constituent minerals are the same as those described, but in the ores from Wheal Kitty a few grains of blende are to be found. The cassiterite occurs as prisms, with the crystal boundaries poorly defined, as irregular masses of small granules, as botryoidal masses of such granules and as spherulitic groupings of thin radiate prisms. The tourmaline is in small blue prisms, embedded in quartz. Fragments of altered "killas" are found in the ore from Wheal Kitty. They are filled with small grains of tourmaline, which are all brown in colour, and contrast strongly in this respect with the blue tourmaline of the "peach." On the surface of those fragments a later growth of tourmaline has sometimes formed in blue acicular prisms, which point outwards towards the centre of the vein.

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## III. Remarks on the Devonian and Caboniferous Rocks in South Devon and Cornwall.

By W. A. E. USSHER, F.G.S.

In order to complete the Dartmouth slate boundaries, and to compare the Devonshire coast sections on the north of the Dartmouth slates with those on the south, some field work in Devon was carried on during the early part of the year.

This investigation was rendered necessary by the results obtained in East Cornwall some years after the districts in question had been surveyed, and to supply indispensable data for the completion of the Memoirs, explanatory of Sheets 350, 355, and 356.

### DEVONIAN.

In the *Summary of Progress* for 1899 (p. 85), the inconclusive character of the evidence as to the position of the Looe fossiliferous beds in the Lower Devonian succession in East Cornwall, is pointed out. In the *Summary* for 1900, p. 60, reasons are given for placing the Looe beds above the Dartmouth slates on the ground of the occurrence of fossils of characteristic Looe types in the Torquay and Paignton Lower Devonian anticlines (in which the Dartmouth slates are not exposed).

In the *Summary* for 1901 the occurrence of a calcareous fossiliferous series in the lower part of the Meadfoot group, corresponding in character to the Looe rocks, and in faulted junction with the Dartmouth slates in the Plymouth coast section, is pointed out.

To complete the stratigraphical evidence, the coast section on the south of the Dartmouth slates had to be brought into direct comparison with the East Cornwall and Plymouth coast sections, and with the coast section south of Berry Head.

One of the chief factors in this investigation has been the occurrence of lenticular grey and red strings and patches of limestone on the East Looe, Millendreath and Tregantle coast. These limestones are often crowded with white, irregular patches of calc spar, which, in shape, suggest the presence of Monticuliporoid corals. This character is by no means uniformly present in the limestone films and lenticles associated with the rocks of Looe (the majority being crinoidal), but, where present, it accompanies the fossiliferous beds, and is easily recognisable. It occurs in the Plymouth coast section, and, in the following notes, will be referred to as the Monticuliporoid type. Stress is laid on this type as the Brachiopods proved too imperfect for identification, time not permitting a protracted search.

*Bigbury Bay Section.*—At Hoist Point the Dartmouth slates contain quartz-albite (pegmatite) veins. At four chains east from Westcombe Beach their reddish, glossy slates are in (probably faulted) junction with dark slates, locally interbanded with pale silty material, and containing occasional beds of grit. These slates (locally stained reddish) give place to an interbanded

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series, with some hard beds of grit and films of crinoidal limestone containing large ossicles as at Tinsey Head. In places the limestone films are of the Monticuliporoid type, and the dark grey colours give place to red. In this series a small thickness of red and dull greenish papery shales with brown fossiliferous films containing crushed Brachiopods and Zaphrentid corals, represents the usual fossiliferous type of the Kingsbridge and Ringmore districts.

The red-stained calcareous beds give place to dark grey slates or shales, with occasional crinoidal films containing *Zaphrentis*, and a fossil also found in the dark slates of Crownhill Bay in the Plymouth section. In these beds in the reefs on the north side of Ayrmer (or Armour) Cove there are hard dark patches, in one of which Mr. Brook-Fox discovered unmistakable *Pteraspis* structure.

On either side of Ayrmer Cove the dark slates contain in places pale yellow-green bands of igneous rock, occasionally with vesicles filled with calc-spar. They also exhibit the pale, straw-coloured variegation so characteristic of slates in the Falmouth district.

On rounding Toby's Point the slates contain dark structureless patches and quartz veins in places, resembling gnarled bedding (so well shown in the Torcross section). The dark colours give place irregularly to red, and the red in one place is anticlined over grey at the base of the cliff. Igneous bands, one of which is evidently folded, are then visible in dark grey, partly reddish, slates containing hard lenticles occasionally suggestive of *Orthoceras*.

The projecting headland south of Toby's Point is chiefly composed of hard, reddish, silty shales apparently disposed in a low anticline and exhibiting a gnarled structure. In these beds red crinoidal limestone films were noticed, and also decomposed brown bands, probably of igneous origin. Further on the red colour gives place to grey. Approaching Challaborough dark grey slates, with or without silty interbanding, when traced on their strike from the beach-reefs, become red in the cliffs, the grey colour sometimes persisting upward to the surface. These rocks are identical with those of the Torcross section, and contain in places impersistent bands of pale sheared igneous rock, never more than three feet in thickness and probably repeated by plication and shifted by small faults or strain cracks. Traces of fossils, mostly replaced by pyrites, are met with. The same mineral is developed on brown-bed bands, and veins of quartz and carbonate occur in the slate, near Challaborough.

At the north end of Challaborough sands a fault, marked by a W.N.W. and E.S.E. channel in the beach-reef, throws dark grey and red (ologiste) splotched slates against red slates or shales with gritty bands (of the Ringmore type).

Between Challaborough and Warren Point the rocks are identical in character with the slates of Toby's Point, the grey



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and straw-coloured variegation and irregular reddish staining in mass being equally noticeable, also the local occurrence of hard lenticles. There are occasional igneous bands resembling a type met with at Darnacombe as well as the Torcross type. South of Warren Point the rocks belong to the same series, the red tints sometimes following the strike, as at the south end of Borough Island. Signs of fossils were noticed on Borough Island near the Pilchard Inn. At the Fish cellars hard igneous rock occurs in red slates or shales.

Between Sedgewell Cove and Sharpland Point red, purple, and grey mottled shaly rocks with brown decomposed fossiliferous seams may be taken as a repetition of the Ringmore fossiliferous beds. Between Sharpland Point and Cockridge Point (at the bend in the Avon) the slates contain much quartz, beds of compact grit or quartzite, interlaminated beds, and a mass of igneous rock with fretted weathering, in shales with red limestone seams, mostly crinoidal, but in part of the Monticuliporoid type. Near this we encounter Dartmouth slates, their purple almost immediately giving place to reddish tints. These slates at Cockridge Point contain *Pteraspis* and hard grit beds, some of which resemble the *Pteraspis* grits of Portwrinkle, etc., in Cornwall. Quartz-albite veins are noticeable at Cockridge Point. The occurrence of this inlier was considered probable but never absolutely proved before.

From Hoist Point to Avon mouth, the fossiliferous Ringmore beds are shown to be of no great thickness. So that the evidence of a broad belt of strata, called the Ringmore group, in which the fossils accompanying similar lithological types recur, is clearly due to plicated repetition.

Toward the mouth of the Avon the Dartmouth slates, probably with fossiliferous beds of the Ringmore type, are concealed by the river sands under which the anticline noses out westward. On the south of the Avon the grey and greenish-buff variegated slates in the cliffs of Hams Sand are a repetition of those of Aymer Cove and Challaborough. In the beach reefs, a large *Pleurodictyum* was found at the south end of Hams Sand. Toward Longstone the section is similar to Torcross, pale masses or bands of igneous rock occur in grey slates with even silty interlaminations in places. Traces of crinoidal limestone (in one spot Monticuliporoid) were detected near Longstone Promontory.

Longstone promontory is composed of red silty shales or slates with beds of grit interpenetrated by quartz; traces of fossils are found in these beds near the coast.

South of Longstone the red colour gives place irregularly to grey, and the section resumes the Torcross type, with the grey and green sheared igneous bands and the irregular grey and red colouring displayed near Toby's Point and Challaborough. Crinoid stems and traces of Brachiopods were noticed in grey slate with silty lenticles near a band of igneous rock at the point on the south of Yarmouth Sands. On the north of the Thurle-

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stone outlier 3 feet of greenish igneous rock occurs in grey brown-banded slates or shales with silty lenticles. Here are also several beds of breccia, probably of volcanic origin, as the traces of shearing seem insufficient to account for them. The rock reefs on the south of Thurlestone sands on which the well-known outlier rests, consist of soft silty grey and reddish slates, and in them also traces of igneous rock are present.

From Thurlestone Cottage to the brown rocks of Hope Headland the section displays no signs of igneous rock. Dark grey slates, locally becoming reddish, with *Zaphrentis* and crinoids in places, make an unsatisfactory junction at Beacon Point with red grit and hard silty slates (containing hard carbonate) with crinoidal lenticles. These gritty beds are overlain by slate with siliceous limestone and hard carbonate bands and nodules and interlaminated beds of the Tinsey Head type. Between Beacon Point and Woolman's Point grey slates, with partly calcareous lenticles and red films, are intersected by quartz veins and overlie a small patch of the interlaminated rocks faulted up at the base of the cliff near Beacon Point. At Woolman's Point a fault brings on silty and calcareous interlaminated beds, succeeded by slates with some hard carbonate veins, thin red films, and very occasional limestone lenticles.

At Mouthwell, the hard silty beds of Beacon Point reappear in plicated association with dark slates containing hard carbonate nodules. There can, therefore, be little doubt that the Beacon and Woolman's Point beds are repeated at Mouthwell, and that the dark slates overlie them. The only question is whether they are above or below the slates on the north. If below, they must be an anticlinal repetition of the Longstone promontory and Ringmore beds. If above, they are the outcrop of a series of grits, which, from their greater development inland and at Beesands, are probably, to a great extent, cut out by fault at Beacon Point. In this case the slates with igneous rocks are lower in the series than those south of Thurlestone Cottage. The east coast section from Hall Sands northward throws little additional light on this question, favouring, if anything, the latter view.

*Torcross Coast.*—In this section the interlaminated beds of Tinsey Head correspond to those of Woolman's Point, and are repeated in an anticline in dark slates on the south. The crinoidal films of Tinsey Head resemble those near Ayrmer Cove, but no Monticuliporoid traces were discovered in them. Near Beesands, interlaminated beds accompany slates containing beds of hard grit. These upper beds are, unfortunately, the only part of the Beeson grits exposed. The slates of Sunnyvale (without igneous rocks) correspond to those between Beacon Point and Thurlestone Cottage. The succeeding rocks of the Torcross Section are the same series as those of corresponding character between Thurlestone Sands and Ayrmer Cove. The fossiliferous Ringmore horizons are scarcely exposed on the border of Slapton Ley, and



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their junction with the Dartmouth slates is not visible on the Strete Gate coast, and is extremely indefinite inland.

*Coast Section South of Brixham.*—At 32 chains from Sharkham Point, volcanic rocks of the Middle Devonian are in faulted junction (inaccessible from the beach) with the Staddon grits. The contorted red grits, slates, and sandstones of this series are succeeded by grey slates at 10 chains from the fault. These slates are probably the upper horizon of the Meadfoot beds, and 3 chains further on assume reddish tints and are intercalated with beds of hard fine-grained grit, which also form more or less lenticular even-bedded masses.

The grits are often thick-bedded, and occasionally exhibit hard, brown, friable surface-patches with fossil cavities. In their prolongation from the north of Southdown cliffs toward Raddicombe, *Homalonotus* was found in a surface fragment. Without this discovery, their correlation with the fossiliferous *Homalonotus* grits, exposed in the New Drive (Torquay Promontory), is extremely probable. They are much plicated, and the argillaceous rocks interbedded with them have escaped cleavage.

These beds are succeeded by pale reddish and grey slates in which contorted bedding is shown in places crossing the cleavage planes. Brown bands of decomposed Crinoidal limestone are visible near 2 feet of red-brown sheared igneous rock. Dark slates with hard nodules, often crowded with small cubes of pyrites, and in places mottled with red (ologiste) splotches, occur for 6 chains to the termination of the cliff near Man Sands Cottage.

On the south of Man Sands the section continues with dark slates, with harder silty interlamination in places, resembling the Torcross beds. On the south side of Crabrock Point this resemblance is further strengthened by the occurrence of greenish igneous rock in dark slates near a fault. We then encounter grey shales or slates with silty bands and seams of Monticuliporoid limestone, followed by red shales or slates with Crinoidal limestone films. These are evidently an anticline of the Looe and Ringmore calcareous fossiliferous beds. Dark slates with green igneous bands, no doubt a repetition of those on the north, come on, giving place at the projection of the coast (10 chains south of Crabrock Point) to a repetition of the shales with Monticuliporoid limestone films.

At the north end of Long Sands, slates with dark patches similar to those at Ayrmer Cove, revealed *Pteraspis* structure, confirming Mr. Brook-Fox's discovery. Interbanded slates and silty beds here occur in the slates, and a Favositid coral replaced by quartz was obtained near their plicated junction with the grits of Long Sands. These grits consist of hard, dense, rather thick-bedded fine-grained, arenaceous rocks or silty greywacke, in which numerous pieces of shale were found along a thin

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horizon. On the surface of one of the beds hæmatitic patches showed numerous traces of small fossils, perhaps gasteropods In the broken receding cliff hard grits and reddish slates occur. At 6 chains from the south end of Long Sands, the grits are in contact with dark slates with red (ologiste) blotches, and these, at the south end of the Sands, give place to dark slates or shales with hard dark patches (similar to those at the north end of the Sands) and with limestone films containing crinoids and *Zaphrentis*. Here, again, we have a resemblance to Ayrmer Cove. A thrust fault, apparently of no great magnitude, occurs here.

The cliff bounding Scabbacombe Sands is composed of dark grey slates, occasionally with pale silty interlamination and bands of grit. At the South end of the Sands a mass of red Monticuliporoid limestone (identical with similar masses on the East Looe Coast) has fallen from the cliff. The cliff, as far as accessible, consists of reddish slates and shales with beds of grit and seams and bands of crinoidal and Monticuliporoid limestone, often decomposed to brown friable residua. The grit fragments on the summit contain traces of Brachiopods.

The junction of these beds (included in the Dartmouth Slates when the district was surveyed in 1890) with the Dartmouth Slates is about 10 chains south of Scabbacombe Sand, where the cliffs are inaccessible. Near this, a band of sheared igneous rock occurs in the Dartmouth Slates. It is probably sheared tuff, similar to the beds at Brookhill near Kingswear, and to bands in the same series near Hoist Point in the Bigbury Bay section.

The identity of the rocks in this coast section, south of Man Sands, with those of the Bigbury Bay and Torcross sections, admits of no doubt. The position of the Long Sands grits, from their character and proximity to slates with *Pteraspis*, is doubtful; as a syncline they would be represented by slates in these sections; as an anticline by the Ringmore beds. Viewed, however, in connection with the Looe area, the impersistent development of such grit masses in these strata is by no means peculiar. The dark slates with nodules at Man Sands may correspond to similar beds at Toby's Point and elsewhere in the Bigbury Bay section. The distribution of the igneous bands differs, as might be expected, in all the sections, and there is very feeble evidence of their occurrence (on the north side of Crownhill Bay) in the Plymouth section.

The effect of the above conclusions on the progress of the work in East Cornwall cannot be overstated. The fossiliferous rocks of Pencarrow Head and Fowey lie to the south of the Dartmouth Slates, and the St. Austell Granite crosses the strike along which, if a persistent outcrop, they should be prolonged to Watergate Bay.

During the latter half of the year, the write was engaged on the survey of the Bodmin Road, Braddock, Boconnoc, and

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Lostwithiel district. The rocks mapped, in descending order as we proceed from north to south, consist of:—

| | |
|---|---|
| Middle Devonian including Eifelian. | Argillaceous slates with silty banding near their junction with the Lower Devonian. Further north, toward the Bodmin Moor Granite, hard dark grey slates with beds of Peek Hill type are met with. |
| Lower Devonian, including the representatives of the Staddon Grits and Meadfoot and Looe Beds. | Pale silty and soft shaly sandstones with hard grits, slates, and shales. Their boundary with the Eifelian runs in a north-westerly direction by Braddock (Broadoak) to Castle Canyke (near Bodmin). Owing to absence of exposures and the plicated repetition of junction beds, its position is often uncertain. The southern boundary of these rocks can seldom be mapped. They give place southward to the Slates, with occasional silty films and beds of grit of the Meadfoot Group, which includes the Looe Beds (of the type of Lanreath and Trelawne). Fossils of Looe types, but badly preserved, were found at Tawell and other places east of Lostwithiel. |

The eastern border of the St. Austell Granite near Lostwithiel is included in the area. The limit of metamorphism is between a mile and three-quarters of a mile from the Granite. Amongst the spotted altered rocks are bedded hornstones of the Peek Hill and Brent type. They are due to the presence of fine calcareo-siliceous sediments or siltstones associated in the rocks of the Meadfoot Group, probably with local traces of igneous rock. Of the latter, the Railway Cutting at Trap Wood north of Lostwithiel affords an example, a sheared pale greenish rock similar to a type common in the Torcross, Thurlestone, and Kingsbridge estuary sections. These traces can only be recognised in actual exposures. A patch of coarse greenstone has been mapped near Brownqueen. A hard dark massive rock, apparently altered diabase, occurs within the limit of alteration at Maudlin.

The porcellanised rocks are quarried near Lostwithiel and in Ford Plantation south of Lanhydrock. They are sometimes banded in light and dark tints. In Brownqueen Wood hard dark rocks are locally developed in dark slates.

In the Eifelian Slates also hornstones are developed irregularly amongst dark slates. The igneous rocks in the vicinity are much weathered felsitic intrusions, occurring west of St. Neots on Goonzion Down and further west near Galgeth and Higher Hill Farm. These Elvans cannot be traced far continuously on the surface. Further south, above the Fish Pond in Glynn Grounds, an Elvan is exposed by the private drive, beyond which it cannot be traced.

Whilst inserting boundaries for the Lower Culm rocks near Newton Abbot, the porcellanised type of metamorphism which occurs near Ilsington was traced to the alteration of fine mudstones in the Upper Devonian. This type of alteration was first distinguished by Champernowne, who described the rocks near the granite of South Brent on his map as "Banded porcellanised felspathic rock" and appends "Axinite" to one of the observations. The same type occurs near Wrangaton, at Ivybridge, and near Dousland and Walkhampton. The rocks occur on the summit of Peek Hill near Dousland, from which the type name is taken

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Banded rocks of a similar type found at Coddon Hill and elsewhere in the Lower Culm induced the writer during the survey of the Brent area in 1895, to regard the occurrence of this type on the borders of Dartmoor as a proof of the presence of that horizon.

The observations made during 1902 near Ilsington, in Devon, and in Cornwall prove conclusively that the type is not confined to any particular horizon, but exists wherever sediments of a certain texture occur in the strata and varies with the association of calcareous bands, volcanic materials and intrusive rocks in the fine sediments.

The Cox Tor and Sourton rocks investigated by General MacMahon, and the Peek Hill rocks described by Mr. Teall in the Annual Report of the Geological Survey for the year 1896, pp. 51 and 52, occur in an area where volcanic rocks are associated with both the Devonian and Lower Culm Measures, hence the prevalence of the igneous type. At Brent the Volcanic rocks are presumably of Middle Devonian age, in both cases the occurrence of fine-grained calcareous sediments is highly probable. That the Upper Devonian slates and mudstones of Ilsington should have been locally somewhat calcareous or indurated by igneous intrusions is also probable. The local presence of calcareous bands and calcareous siltstones in the Middle Devonian and Lower Devonian (Meadfoot and Looe beds) is characteristic.

The same type of alteration has been noted at Camelford and in one spot on the east margin of Bodmin Moor; in both cases it is very restricted.

The rocks of the Peek Hill type are quarried for road metal in the Lostwithiel district, and in the Brent and other Devon localities. The Eifelian mudstones, and the silty and argillaceous rocks in the Lower Devonian which resemble them, are quarried for building purposes, the laminæ or cleavage planes in both types being coherent and joints or planes of schistosity occurring in such a way as to yield large blocks.

## CARBONIFEROUS.

The writer was engaged for a fortnight on field work in the Newton Abbot area, where a boundary had not previously been drawn between the Lower Culm Measures and overlying shales and grits. At the same time the conglomeratic greywacke beds of the area were carefully noted with the view of explaining the enigmatical occurrence of the greywacke sandstones of the Plymouth and Saltash area (of Efford and Wearde Quay) to which a similar date of formation has been assigned. To ascertain the very intricate relations of the rocks between Bickington, Ilsington, and Bovey Tracey (mapped without subdivision of the Culm in 1887, on the old one-inch map) it was found absolutely necessary to re-map four square miles on the six-inch scale.

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In the Lower Culm succession in the Ashton and Trusham district the *Posidonomya* and *Goniatites spiralis* beds (hard mudstones, shales, and occasional seams or beds of limestone) overlie chert beds succeeded by hard dark mudstones and dark shales. This section, in the road from Farley to Trusham station is the most complete one in the district; the chert beds in it are of no great thickness (perhaps 20 feet) and are separated by volcanic tuffs from the *Posidonomya* bed above.

Skirting the granite to Bovey we encounter in the altered rocks of the Lower Culm many intrusive masses of greenstone, and occasional bands which seem to be contemporaneous felspathic tuffs. These felspathic bands occur near Stickwick and Bovey Tracey. The railway cuttings from Bovey towards Lustleigh display dark shaly rocks which may be included in the Middle Culm. A mass of felsite occurs on the margin of the granite near Woolley. This rock is for the most part coarse, at first sight simulating a Culm conglomerate owing to blebs of quartz, pieces and granules of a black substance, probably schorl rock, and pieces of felspar. Felsite is again seen by the railway where it bends northward to Lustleigh, and near this, towards Hisley, a mass of altered greenstone is in contact with the granite. There are eight patches of greenstone in the doubtful Middle or Lower Culm rocks between this mass and Bovey Tracey. From Yarner Wood southward to Bickington the boundaries between Lower and Middle Culm were traced, although there are numerous faults which bring up inliers of Upper Devonian. The hard shales with *Posidonomya* were identified and also chert beds, which rest on the Upper Devonian near Liverton. Out of ten patches of intrusive greenstone in this district two occur in the Upper Devonian inliers and eight in the Lower Culm. The Ashton and Trusham districts exhibit the same absence of intrusive rocks in the Middle Culm Measures. From Doddiscombleigh on the north to Bickington on the south, this main outcrop of Lower Culm rocks passes under dark slates, with hard beds of greywacke grit and sandstone more or less fine in grain and with no traces of conglomerate.

The Ugbrooke Park greywackes exhibit every variety of grain from a fine dense rock to a conglomerate containing stones from a quarter to half an inch in diameter. In many respects these greywackes are the counterparts of the Wearde-Efford beds, and of the Middle Culm greywackes of the Tavistock district and the St. Mellion outlier in Cornwall. All these, especially the coarser varieties, show derivation from igneous and fine-grained sedimentary rocks. In the coarser beds of Ugbrooke Park, south of Oldchard and Ideford, and in the faulted outliers between Newton Abbot and Ipplepen, the sedimentary fragments include a fair percentage of Lower Culm chert, and of fine-grained dark rocks, no doubt also derived from the Lower Culm. The sedimentary inclusions in the Wearde-Efford greywacke are generally of dark shale, but pieces of (Culm?) chert were obtained in a coarser band near St. Erney, in East Cornwall. The conglomerate beds in all the above districts contain besides

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quartz a large percentage of igneous fragments of various kinds, and many of the harder fragments are well worn.

Wherever the Ugbooke Park greywackes are in unfaulted relation with the numerous inliers of Lower Culm they are found to rest on the *Posidonomya* (or *Goniatites spiralis**) beds. The chert beds are not exposed in these inliers although they must be represented in the area, as two small faulted patches have been recognised, one near Chudleigh (north of Lawell House), the other near Bishopsteignton (north of Coombeway).

The greywackes rest in places (as at Gappagh and in the outliers between Newton Abbot and Ipplepen) on dark irregular shales which may (as west of Bovey Tracey) belong either to the Middle or Lower Culm. These broken shales occur at Bishopsteignton, and have been mapped as Culm measures. The Efford greywackes near Plymouth rest on similar shales. In the Tavistock volcanic district the same difficulty as regards the occurence of dark shales of doubtful character exists.

At Beer Alston Station an outlier of greywacke rests on some beds of grey chert, whilst elsewhere nothing intervenes between its base and the Upper Devonian. In the St. Mellion outlier the *Posidonomya* beds, chert beds, and dark mudstones and shales are represented, apparently in normal sequence, below the Middle Culm greywacke. There is a small outlier of black Culm chert on Upper Devonian slates near Tamerton Folliott. At Wearde, south of Saltash, the greywacke rests on dark slates or shales, on Dolerite, and on volcanic rocks. As far west as Padderda, near Menheniot, traces of greywacke are met with, often accompanied by the equivocal dark slates or shales, and always amongst volcanic rocks, and Upper Devonian slates. In these cases no boundary can be satisfactory drawn to separate the Middle Culm greywacke from the Upper Devonian. For two years after their discovery in 1893 and 1894, the writer regarded the Wearde-Efford greywackes as contemporaneous with the volcanic rocks in the Upper Devonian. Subsequent field work in the Culm Measures of the Tavistock and St. Mellion district corroborated by the petrological examination of the rocks by Professor Watts, (which showed that whilst none of the specimens gave conclusive evidence of contemporaneous volcanic activity "angular fragments of many rocks such as felsite, andesite and micropegmatite," and quartz grains often strained, suggested the denudation of a volcanic series, and of gneissose or schistose rocks), and by the discovery of chert in the greywacke at St. Erney, led him to correlate them with the Middle Culm.

The collective evidence, which must remain incomplete until the area west of Dartmoor is re-surveyed, suggests some such explanation as the following. During the final stages in the deposition of the Upper Devonian vulcanicity from local centres prevailed, in places continuing during the formation of the Lower Culm rocks. The elevation that succeeded the deposition

* In Dr. Woodward's list of fossils from these beds near Waddon Barton, *Goniatites spiralis*, the most abundant form there, is omitted.

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of the Lower Culm, although universal, was not uniform. Over a large part of the area the later stages of this movement were so gradual and uniform that the *Posidonomya* shales and limestones seem to pass up into the plant-bearing grits and shales. The section at Perridge Tunnel on the new line from Ashton to Exeter, and some of the Bampton quarries bear out this view.

Over those parts of the area where the crust had recently been weakened by volcanic activity and igneous intrusions, irregularities in elevation would have led to the destruction and dispersal over the shallow sea-bed of such Volcanic and Lower Culm rocks as had thus been exposed to denudation. The occurence of the Wearde-Efford greywacke, and the local irregularities in junction between Middle and Lower Culm of which the Bere Alston outlier is an example, point to this conclusion.

The faults and plications in the Lower Culm render it impossible to form any absolute estimate of their thickness. There is no doubt that their constituent hard shales and limestones, cherts, and shales form horizons which exhibit a reciprocal thinning and thickening—and there are indications of the prevalence of the dark shale and mudstone type in volcanic areas. A thickness of 300 feet, may be considered too liberal an estimate for their maximum development.

## IV. The Coal Measures of Llanelly, Llannon, and Cross Hands in the South Wales Coal Field.

By A. STRAHAN, M.A., T. C. CANTRILL, B.Sc. and E. E. L. DIXON, B.Sc.

Mr. Strahan. The past year's work in the Coal Measures has been carried on in the North Crop near Cross Hands and Pontyberem by Mr. Cantrill, in the Pennant region near Llannon by Mr. Dixon, and on the south side of the Coal Field around Llangennech, Llanelly, and Pembrey by Mr. Strahan.

### SOUTHERN REGION.

The South Crop lies under Carmarthen Bay, and the main synclinal axes of the Coal Field pass, the one under Llanelly and the foreshore near Pwll and Pembrey, the other under the sea, where its position remains to be proved. The Llanelly syncline, in conjuction with a series of faults all throwing down to the east, introduces the highest measures existent in the Coal Field. The highest known coal is believed to be one found near Gelli House some distance above the Gelli Vein, but possibly still higher measures are thrown in by the Plas-isaf Fault under part of the Loughor Valley.

In the Summary of Progress for 1901 allusion was made to the difficulty of identifying the Grovesend Veins. Though some uncertainty still exists as to their exact position in the series, much light has been thrown on the question by information supplied by Messrs. Thomas Williams & Sons, and by Mr. John Roberts. In the first place it seems to have been proved beyond doubt that

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the fault by which these veins were thrown down against the Swansea Four-feet Vein in the Mountain Colliery was of great magnitude. It not only had that appearance, but a bore-hole put down near the mouth of the Mountain Drift failed to prove the Four-feet Vein within 200 yards of the surface. The sinking of the Cefn-arda Shaft has confirmed the fact that a great thickness of barren measures underlies the Grovesend Veins. Starting about sixty yards below the Lower Vein of the Grovesend group this shaft proved no coal worthy of mention until it reached a depth of 255 yards, when the following seam was traversed:—

*Supposed Four-feet Vein, Cefn-arda.*

| | ft. | in. |
|---|---|---|
| Clift | | |
| Coal | 2 | 0 |
| Stone | 1 | 0 |
| Coal | 1 | 0 |

The identification of this seam as the Swansea Four-feet involves its correlation with the Big Vein or Six-feet of Llanelly. Unlike as the two seams are, the correlation is not improbable. The Four-feet, as proved in the region of Gorseinon and Pontardulais, is far inferior to the same seam as proved in the South Crop and near Llanelly, while still further north it appears to share the fate of the Five-feet, Hughes Veins and others, and to pass into a mere smut. A shaft at Pontardulais, two and a half miles north of Cefn-arda, proves the Four-feet Vein as follow:—

*West Merthyr Pit, Pontardulais.*

| | ft. | in. |
|---|---|---|
| Shale | | |
| Coal | 1 | 10 |
| Rashes | 0 | 8 |
| Coal | 0 | 8 |
| [Rashes] | 1 | 3 |
| Coal | 1 | 0 |

Against the identification of the Cefn-arda Seam as the Four-feet, it may be urged that the seams which usually lie above the Four-feet have not been detected. At Pontardulais, in the West Merthyr Pit, a coal, 1 foot 1 in. thick, and corresponding possibly to the Loughor Little Vein, lies 18 yards above the Four-feet. Above this again is the Pen-ys-callen Vein which is believed to crop 300 yards south of the shaft, and the Stinking Vein which is being worked by slant 600 yards south of the shaft. Turning to the neighbourhood of Loughor we find that the Pen-ys-callen Vein has been much worked and that the Stinking Vein has been proved 30 yards above it, while the Broadoak Shaft shows that the Pen-ys-callen and Loughor Little Veins lie 63 and 43 yards respectively above the Swansea Four-feet Vein. Again in a westerly direction the shaft of St. David's Colliery shows a seam 57 yards above the Swansea Four-feet, another 69 yards above that coal, and the Gelli Vein 189 yards above that coal. The Cae Colliery shaft passed through the Clement's Vein 44 yards above the Swansea Four-feet, a seam 2 feet thick 42 yards above the Four-feet, and another 19 yards above that vein.

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Of the veins here mentioned, none quite correspond in position to the Grovesend group on the supposition that the seam proved at Cefn-arda is the Four-feet. The Gelli Vein comes nearest, but whereas the Grovesend Lower Vein appears to be more than 300 yards above the vein in Cefn-arda shaft, the Gelli Vein lies less than 200 yards above the Four-feet (or Box Big Vein) at St. David's. To this must be added the fact that no equivalent of the Stinking, Pen-ys-callen or Loughor Little Vein has been recognised at Cefn-arda.

So far the identification of the Cefn-arda Seam as the Swansea Four-feet appears to be contrary to evidence. It is difficult, however, to see what other correlation is more probable, for there is no such mass of barren measures known in the neighbourhood as has been proved in the Cefn-arda Shaft. If the seam represents the Swansea Five-feet, the absence of the Swansea Four-feet remains unexplained; if it represents the Swansea Six-feet, the absence of both the Four-feet and Five-feet has to be accounted for.

An objection to the correlation of the Cefn-arda seam with the Four-feet, which was mentioned in the *Summary of Progress for 1901*, p. 45, lay in the fact that it implied a throw of not less than 200 yards in the fault proved in the Mountain slant, although no fault of such magnitude had been recognised either to the north or south of the spot. That none can be traced more than a mile to the south is true, but the past year's work has shown reason to believe that the Mountain Fault not only continues northwards, but that it forms one of a series of great easterly downthrows. The evidence lies in the positions of the group of seams known as the Fiery (Swansea Six-feet), the Golden (Swansea Three-feet), and the Bushy (Swansea Two-feet) to the west of Pontardulais.

The Graigola or Six-feet Seam can be traced continuously along the north-west side of Cefn Drum as far as the fault which runs from Gorseinon by Bolgoed, and thence probably to Glyn Wallis. This fault, being a downthrow west, must throw the crop of the Six-feet northwards, and accordingly at Tal-y-fan we find a seam in about the expected position. The coal was worked in 1877 and proved to be 3 feet 9 inches thick and solid, therein differing from the Six-feet Vein of Birch Rock which always contains a parting. It was believed, however, to be that vein, and a trial-pit in a field close by proved a seam 22 inches thick, at a depth of 22 yards, which was thought to be the Swansea Two-feet. The workings encountered faults in every direction and were abandoned without anything definite having been proved, but the evidence as to the position of the Four-feet, afforded by the West Merthyr Pit previously mentioned, goes far to prove that the Tal-y-fan Vein must be either the Six-feet, or one of the group to which that vein belongs. If it is the Six-feet the absence of any known outcrop for the Five-feet Vein may be attributed to the highly disturbed state of the ground.

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Crossing now to the west side of the Loughor we find a vein being worked at Fforest and cropping close to Pontardulais Bridge. The coal is 2 feet 9 inches thick and is considered to be the Swansea Five-feet Seam. To the south of and above it there crops out a massive sandstone which is quarried at Hendy, but all overlying rocks are concealed by gravel and alluvium. To the north there rise from beneath it the sandstones and shales of Fforest, and at their base a group of three seams which have been worked round the north slope of the hill. These may be taken to represent the Six-feet, Three-feet, and Two-feet, and to confirm the identification of the Fforest seam as the Five-feet, the Four-feet presumably cropping under the gravel near Hendy. If now we consider the relative levels of these veins with those of Pontardulais we find that a large easterly downthrow must intervene. The Swansea Five-feet of Fforest, for example, is approximately on a level with the Pen-ys-callen of Pontardulais, from which the throw of the fault may be inferred to be about 200 yards. By some authorities the Fforest seam is thought to be the Swansea Four-feet, in which case the throw of this fault would be about 100 yards less, but another, presently to be mentioned, correspondingly increased.

The fault thus inferred may be supposed to run near Pontardulais Bridge and along the Loughor towards Llanedy. It helps to account for the form of the valley, which is unusual in respect of the facts that it is broad, and that it is divided into two branches by the rock-hills of Tal-y-fan and Tyn-y-bonau. The Loughor runs now on the west side of these hills, but there is an almost equally deep and broader depression on the east side. The two depressions correspond locally to, and no doubt have been determined by, the two faults described above. Southwards the fault ranges for Waun-gron, where there is evidence of disturbed ground, though it has not been reached in the workings of the Grovesend Seams. The line continued in the same direction leads to the point where the Mountain slant passed from the Grovesend Lower Seam into the Four-feet. Still further south it may be identified in an easterly downthrow proved in the old workings under Loughor Common, the position of which is recorded by a stone marked "falt," while further on again it appears to be the fault which limits the workings in the Five-feet from Cae Duke. This is the last known of it, unless it can be proved to cross the alluvial tract to Gurnos where is an easterly downthrow in the Three-feet and Two-feet veins.

The second of the series of easterly downthrows runs along the Gwili valley. On the west side of that valley the Golden Vein (Swansea Three-feet) is being worked for clay at the Tal-y-clyn Brickworks, while the Fiery (Swansea Six-feet) and the Swansea Five-feet have been proved in their proper relative positions. The Swansea Five-feet was worked by a slant 350 yards south of Tal-y-clyn-uchaf, on the west side of the fault, and by a level at Felin Fforest, nearly a mile further north, on the east side of the fault. Assuming the dip to average 6 inches to the yard, this displacement of outcrop implies a vertical throw of about 290

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yards, or if the Fforest seam be the Four-feet, the throw would be about 390 yards. The fault is believed to run close to Tal-y-clyn-uchaf, passing thence under the alluvium and across the higher ground about 200 yards west of Pen-yr-heol. Eighty yards west of that house a fault was touched in the Mountain workings, but the form of the ground suggests that the main fracture may lie a little further west as stated. Continued southwards the line falls nearly into that of the Pengrys Fault, which, however, is a downthrow west.

The third of the series of easterly downthrows has been proved at the Morlais Colliery to have a shift of 45 yards. It runs under a ravine 400 yards north-east of Tal-y-clyn-isaf and thence under Pen-lan. Southwards it passes into unproved ground under the alluvium and gravel of the Loughor.

The fourth of the series is known as the *Plas-isaf Fault*. It has not been actually proved under the Loughor at Loughor, but its effects were seen in the easternmost workings of the Golden and Fiery Veins from Bynea. The level course turned abruptly from E. 18° S. to north and south, at a point nearly north of the Yspytty Works, and the veins assumed an easterly dip. Disturbed ground was reached from Broadoak also in the Swansea Four-feet Seam, nearly under the centre of the tidal area. The displacement was estimated at 200 yards. Northwards the line of fault is more clearly defined; it runs almost exactly under the Llanelly and Llangennech Railway past Plas-isaf Colliery, a slant 500 yards south of that colliery having started in it. At Llangennech a trial-pit proved what is supposed to have been the Gelli Vein on the east side, while the Box Big Vein (Swansea Four-feet) crops closely on the west side, the throw here being a little less than 200 yards. The fault is well exposed in the Morlais 400 yards north of Llangennech Mill, and runs along the east side of the Morlais Valley, cutting off the crops of the Swansea Five-Feet at Tir Eglwys and those of the Fiery, Golden, and Bushy in succession. The displacement of outcrop of the Big Vein amounts to 1,400 yards. The Plas-isaf Fault is not known in Gower, the only fault which lies in its range being a downthrow west.

The fifth of the series of easterly downthrows is known as the *Bryn-serfyll Fault*, and has been proved in all the seams from the Llandilo branch of the Great Western Railway as far north as Clyn-gwernen, where it cuts the outcrop of the Llanelly Four-feet (Five-feet) Vein. Farther north it can be traced for some three miles by surface-evidence, passing about 300 yards west of Clochyrie. Near Dafen its throw appears to be about 245 yards from the fact that the Gelli Vein was reached at 56 yards depth in the Gelli Pit on the east side, while the Box Big Vein crops out close by on the west side. The distance between these two veins is 189 yards as proved at St. Davids.

The sixth easterly downthrow is known as the *Box Fault or Box Great Bar*, a small fault about 150 to 250 yards west of it being known as the Little Bar. The Box Fault may be seen cutting through the Pennant rock of the Pen-y-fan quarries, and

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has been proved thence northwards in the principal veins as far as Box Cemetery. There an old level, said to have been the Rosy Vein, is nearly opposite old crop-workings in the Box Big Vein, which would imply a displacement of about 150 yards, but the crops of the Fiery, Golden and Bushy indicate a considerably smaller shift. The fault, however, can be traced for more than a mile north of Felin-foel by its effect upon the succession of outcrops of small veins below the Bushy. The line thus evidenced runs about 100 yards west of Llwyn-y-piod.

The seventh easterly downthrow is known as the *Stradey Fault*. It was worked up to in the Golden Vein and others from the Old Castle Pit and proved to run at the foot of the steep Pennant hill of Stradey Wood, through Cwm-bach. Inasmuch as it threw out all the seams down to the Bushy, the determination of its throw depended on the identification of a vein worked on its west side at Pwll with one of those which underlie the Bushy at Cille, a matter which is discussed later on. It was estimated that the throw could not be less than 200 yards, and was probably as much as 280 or 290 yards. Two other faults were proved in the Old Castle workings, and were known respectively as the Nine-fathom and Twenty-eight-fathom Faults. Both were downthrows to the west.

The eighth easterly downthrow cuts off the Pwll workings and crosses the hill 200 yards east of Moreb to Gwr-aeth. The throw is small as compared with those previously described. Others have been proved at Burry Port and west of Pembrey but none were of the first magnitude.

The faults enumerated above all belong to the N.N.W. system which is so conspicuous throughout the South Wales Coal Field. Their age has been discussed and the conclusion formed that though they break through the Trias and Lias, they were partly also of earlier date, inasmuch as their effects are greater in the Carboniferous than in the Secondary Rocks. However, this may be, the fact that they cut right across the structures due to the pre-Triassic folding of Gower and Carmarthenshire is obvious, and is unusually well illustrated in the area surveyed during the past year.

The town of Llanelly stands in the centre of a deep syncline which has been traced continuously from the Loughor to Burry Port. The fold may perhaps be regarded as commencing between the Lliw and the Loughor, where a syncline was proved in old workings in the Four-feet Vein under Loughor Common. The synclinal axis trended nearly N.W. in the direction of Ty-coch on the west of the Loughor, where the Llanelly syncline is well developed.

At Ty-coch it is possible to see in the low cliff much of the structure which characterises the syncline in its course through the Pencoed, Cae and Old Castle collieries. On its south side the dip is always steeper than in the north, and in places reaches an angle of 45°. In the immediate neighbourhood of the bottom of the trough in the Pencoed Colliery the dip increases almost to verticality, and the veins have proved unworkable for

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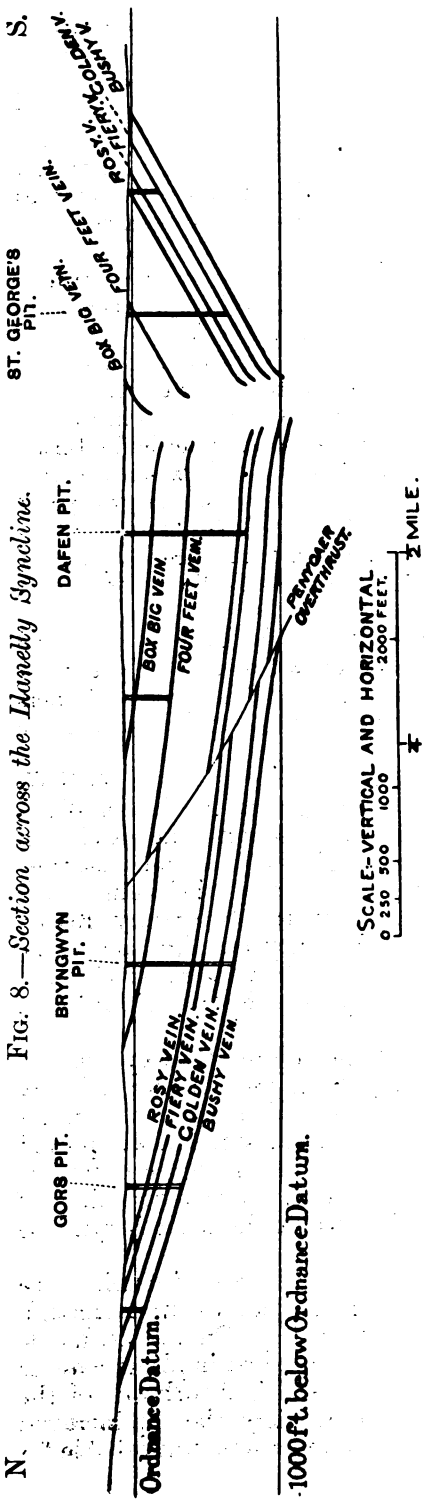


FIG. 8.—*Section across the Llanelly Syncline.*

a breadth of some three or four chains; to the north of the trough the veins come again into their proper positions and rise gently up to their north crop. The axial plane of the syncline thus proved in the successive seams is inclined to the south at a high angle, so that its position at the surface lies considerably to the north of its position in the Fiery group of veins. Another interesting feature in the structure which was proved at Dafen, and is known as the Pen-y-gaer Fault, consists in an overthrust ranging east and west and cutting the veins as they rise northwards from the trough. It hades south at an angle of about 30° from the horizontal, and causes an "overlap" of about 20 or 30 yards in the veins. The section forming Fig. 8, which is reduced with slight modification from a plan in the possession of Messrs. Nevill, Druce and Co., gives a vivid representation of these structures, and of the effect of the wave of compression from the south to which they were due.

The description given above applies to the region west of the Box Fault, except that at the Old Castle and Pwll Collieries the synclinal axis was not broken, and there was no overthrust corresponding to the "Pen-y-gaer Fault." The dip however averaged 14½ inches to the yard on the south side of the trough, as compared with 6 inches to the yard on the north side.

The axis of the syncline runs under low ground generally and under a broad foreshore from Llanelly westwards Northwards from it

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the Pennant rocks rise into characteristic hills, but there is no corresponding outcrop on its south side. The explanation is found in what is known as the "anticline," which, however, may be more correctly described as a series of step faults accompanied by a flattening of the measures. The existence of the structure is of the greatest importance with respect to the quantity of coal existing under the foreshore and estuary, but has been proved for a short distance only. No clue whatever to its existence is visible on the surface.

The "anticline" was proved in the Carnarfon Pit near Dyffryn. To the north of the colliery the Rosy, Fiery, Golden and Bushy Veins crop in their proper places on the south side of the syncline, the Bushy coming near the surface close to the pits. The more northern of the two pits however, was sunk on a fault with a downthrow south, and in working the coal north of Dyffryn Crossing, this disturbance was found to consist of a series of step-faults all downthrows south, as many as five having been proved before it became impracticable to follow them down any further. The net result is to throw the Rosy, Fiery, Golden, and Bushy Veins in again; the Rosy was proved at 48 yards depth in the southern Carnarfon Pit, and the Fiery at 24 yards depth in an air-pit 50 yards north of Dyffryn Crossing. The Golden was proved at 38 yards depth in a pit on the south side of the railway 580 yards further west, and at 34 yards depth in a pit 200 yards west-north-west of Bryn Carnarfon. The Bushy was proved at 70 yards depth in the Caedu Pit 150 yards east of Bryn Carnarfon, and at 42 yards in the Tir-bacas Pit. The aggregate throw of the step-faults may be estimated by comparing the positions of the Rosy and Bushy Veins at Carnarfon; the former in the south pit is about 43 yards below the position of the Bushy on the north side of the "anticline." The Rosy should be about 88 yards above the Bushy, from which it would appear that it is thrown down 131 yards; but the estimate is not wholly reliable, for there are said to be other faults, one for example under the Great Western Railway.

The Bushy Vein was followed southwards from the Tir-bacas pit for a distance of 7 chains with a rise of 1 in 3½, when it was thrown out by a fault, parallel to the "anticline," but with an upthrow south. The throw of the fault was not ascertained inasmuch as it threw the Bushy Vein out, and the ground south of it remains unknown.

Returning now to the "anticline" we get proof of its approximate course westwards near Llandilo Crossing, where Evans Pit proved the Bushy at 40 yards depth. As that vein crops in the south side of the syncline some 600 yards farther north, there is evidently a large downthrow south between that crop and the pit.

The line thus indicated prolonged for a mile westwards brings us to the Pen-y-fan quarries. The rock there worked is a massive sandstone lying some distance below the Bushy Vein. It dips north, but at about 13° only as compared with the dip of about 29° which prevails at St. George's. To this fact, which



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in itself suggests the neighbourhood of the "anticline," may be added the existence of a small east and west fault with a down-throw south. The fault follows the foot of the sandstone-scarp, and is likely to be the first of a series of steps such as those which constitute the "anticline" farther east. The direction of the anticline at Pen-y-fan, as suggested by the form of the ground, appears to be due east and west, while its general course thence to Carnarfon Pit is about E. 14° S., but it must be remembered that it is crossed by the Box and Bryn-serfyll faults and probably shifted by both. Westwards from Pen-y-fan it appears to range for the new dock at Llanelly, but though the rock was exposed in the dock-bottom the existence of the "anticline" was not determined, for the dip was northward at a high angle. It may be mentioned, however, that a coal-crop was disclosed, about the identity of which there is some doubt. It is commonly supposed to have been the Bushy Vein, but it occurred near the south end of the dock at a distance of 750 yards south of the Old Castle Pit. The Bushy Vein was 185 yards down in that pit and is shown on the plans as cropping about 500 yards south of the pit, with a rise of 22° (14½ inches to the yard). Moreover, the seam exposed in the dock was double, and consisted of an upper coal, 2 feet 6 inches thick, and a lower coal, 1 foot 4 inches, with clay between, whereas the Bushy Vein is said to have been a solid coal, 2 feet 10 inches thick.

Two trials on the south side of the "anticline" have still to be mentioned. One known as the Great Morfa colliery is situated on the sea-bank 600 yards north of Penrhyn-gwyn. The following section of the pit and borehole is condensed from an account supplied by Mr. W. Watkeys:—

*Great Morfa Colliery.*

| | ft. | in. |
|---|---|---|
| Filling up to level of bank | 8 | 0 |
| Soft clay with two beds of peat, the lower 30 feet below the top of the pit | 32 | 6 |
| Quicksand | 2 | 0 |
| Gravel | 22 | 0 |
| Measures | 32 | 10 |
| Coal No. 1 (a good bituminous coal; further east 3 ft. thick) | 2 | 6 |
| Measures | 139 | 8 |
| Coal No. 2 (further east 2 ft. thick) | 1 | 6 |
| Measures | 174 | 1 |
| Coal | 1 | 1 |
| Measures | 12 | 2 |
| Coal | 0 | 8 |
| Measures | 38 | 6 |
| Coal | 0 | 7 |
| Measures | 1 | 9 |
| Coal | 1 | 0 |
| Measures | 57 | 4 |
| Coal | 1 | 6 |
| Measures | 6 | 9 |

The dip was 1 in 9 in a direction S. 11° W. None of the coals proved were identified.

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The second trial referred to was near Tir-morfa-fawr. Two shafts were sunk and a coal 1 feet 6 inches to 2 feet 3 inches in thickness was proved at a depth of 70 yards, which was thought to be Cille No. 2 Seam. The dip was gentle in a direction slightly west of south. The southerly dip seen in both the Great Morfa and Tir-morfa pits proves that the bottom of the syncline which runs between Gowerton and Loughor must be still further south, and the true South Crop of the Coal Field further south again. As a matter of fact a line of level course through the Morfa Colliery runs parallel to and only 1 mile 270 yards north of a line of level course in the Penclawdd Vein at the Penlan Colliery in the South Crop in Gower. The Penclawdd Vein runs through Gower at a distance of nearly 1¾ miles south of the Gowerton syncline. It seems probable therefore that the South Crop and the syncline must get narrower westwards. The effect is such as might be produced by the syncline becoming shallower in that direction, as indeed is known to be the case in the Llanelly syncline.

The Stradey Fault throws out the Bushy Vein, the lowest of the group which has yielded the bulk of the coal near Llanelly and Swansea. West of it several coals have been worked in the Pennant, and among them should be found the representative of the Hughes Vein. The succession can be determined by crossing the outcrops either northwards on the east side of the Stradey Fault or westward where they come down in succession to the coast-line west of that fault. North of Llanelly they have been worked by a level at the Cille Colliery. Four seams, known as the Cille Nos. 1, 2, 3, and 4, were proved and No 2 has been worked. At the mouth of the level a borehole was put down through and below the same measures. It started about 70 feet below the Bushy Vein and proved the following seams:—

| | ft. | in. | | ft. | |
|---|---|---|---|---|---|
| Cille No. 1 Seam | | 10½ | thick at | 166 | depth. |
| Cille No. 2 Seam | 1 | 11 | „ | 202 | „ |
| Cille No. 3 Seam | 1 | 6 | „ | 272 | „ |
| Cille No. 4 Seam | 1 | 7 | „ | 333 | „ |
| Coal | | 5 | „ | 557 | „ |
| Coal | 2 | 2 | „ | 655 | „ |
| Coal | 1 | 0 | „ | 659 | „ |
| Cille No. 5 Seam | 2 | 4 | „ | 664 | „ |
| Cille No. 6 Seam | 1 | 3 | „ | 887 | „ |

Of these, No. 2 crops out by the side of the road to Five Roads; No. 4 crops out at Cilau-gwyn; No. 5 crops out near Pant-y-llydu-fach; while No. 6 may be a coal which has been worked at Trefanau and is said to be 3 or 4 feet thick. As far as Trefanau and for 800 yards north of it the sequence continues unbroken, but the dip steadily increases up to nearly 50°. The beds then turn over and dip gently to the north, with signs of overthrusting. What appears to be the crest of the anticline and principal overthrust is still under investigation, but it may



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be mentioned now that a quarry in a dingle on the west side of the Mynydd-mawr Railway, 600 yards south of Horeb, gives a remarkable view of a part of the structure. The quarry has been opened through some few feet of completely ground-up rock into a hard thin-bedded sandstone below. The plane between the two is clean-cut and slants down southwards at 16°; the rock beneath it dips north at 12°, but in places, just below the plane, the edges of the beds have been doubled back. It is to be noted that this overthrust ranges east and west and "dips" south as does the "Pen-y-gaer Fault," that the burring of the edges of the beds shews the overthrusting to have taken place from the south, and lastly that the rocks above the plane are disintegrated, while those below are sound and hard.

We have now to pick up the equivalent of the Cille veins on the west side of the Stradey Fault. Working northwards, as before, we pass the following outcrops. The Pwll Vein and the Little Pwll Vein, 35 yards above it, crop at the Stradey Stables, through Stradey Wood, and reach the edge of the marsh some 300 yards west of Pwll Colliery. The Pwll Vein was reached at 50 yards depth in the shaft of that colliery and was worked under the foreshore for about 800 yards south of the Great Western Railway, the coal being followed continuously down to the bottom of the Llanelly syncline and up the rise to the south of it.

The next seam in descending order has been worked near Cil-y-maenllwyd and is known by that name or as the Weasel or Shenkin Vein. It is said to be 18 inches thick, but appears to be quite local. A more constant seam is now being got at the Cwm-mawr Colliery and has been worked south-east of Gwr-aeth. It is said to be 22 inches thick. The Cwm-mawr Vein is thought to be the Pant-y-llydu-fach or Cille No. 5 Vein of the east side of the Stradey Fault.

Another clue to the identification has been found in the Pwll Veins. The vein proved in the Cille Borehole at a depth of 557 feet, and the ground immediately above and beneath it, is supposed to be identical with the Little Vein now worked at Pwll Level. If this be so, the vein, 2 feet 2 inches thick, proved in the borehole at 655 feet depth, will correspond to the Pwll Vein, but on this supposition Cille No. 5 is too close under the supposed Pwll Vein for the Cwm-mawr Vein. Further discussion, however, on the correlation is reserved until the ground west of the Stradey Fault has been examined.

The workings in the Pwll and Cwm-mawr Vein are limited on the west by a downthrow east which passes 200 yards east of Moreb. The effect is to throw the outcrop of the Cwm-mawr Seam under the foreshore, where its position has not been determined, while the next seam below, known as the Clay Seam, is thrown nearly into the position that would have been occupied by the Cwm-mawr Vein in the absence of the fault. The Clay Vein is about 1 foot 6 inches thick and is worked for its under-

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clay for the manufacture of firebricks. Its crop runs by Lletty'r-ychen-fawr and Plas-newydd. Four hundred and fifty yards to the north of it we reach a well-marked group of coals with soft measures, the outcrop of which is marked by the deep strike-ravine of Cwm Ierman. Four coals occur, namely, the Gyscwm Rider, the Gyscwm, the Rhengog-fach and the Rhengog-fawr.

Below the Rhengog-fawr there comes an extremely massive rock, about 500 feet thick, below which lies the Cenrhos Vein, 4 feet thick. The Gyscwm Vein crops close to Achddu Mill and passes thence under the gravel to near Furnace, whence it strikes across the hills by Pen-llwyn-isaf, its position marked everywhere by a depression dominated on the north by the outcrop of the Cenrhos Rock. The Cenrhos Vein on the other hand crops in the high plateau, there being comparatively little soft ground associated with it.

It will be noticed that there are two breaks in the continuity of the sequence, both due to faults, namely at Stradey and Moreb. In both cases an examination of the country further north is likely to furnish the evidence necessary to complete the sequence, but at present we have not the data for estimating the distance between the Cwm-mawr and Gyscwm Veins, further than that the former is said to crop near the mouth of the New Lodge Level, while the latter is reached in the level 670 yards from the mouth. With a dip of 1 in 3 this indicates a distance of about 215 yards between the two veins, vertically to the bedding. In the same level the Clay Vein was reached at 300 yards from the mouth, or about 95 yards below the supposed position of the Cwm-mawr Vein.

From the Clay Vein downwards the sequence has been proved in various levels and shafts. The detailed measurements were incorporated by Sir W. Logan in Sheet 1 of the Vertical Sections of the Geological Survey, from which the following abstract is taken:—

| | ft. | in. |
|---|---|---|
| Sandstone with some beds of shale | 200 | 0 |
| Clay or Gwdig Vein | 1 | 2 |
| Shale with a few thin bands of coal | 70 | 0 |
| Sandstone with some beds of shale | 255 | 0 |
| [Gyscwm Rider] impersistent | | |
| Shale [expanding rapidly from east to west] | 27 | 0 |
| Gyscwm Vein | 3 | 0 |
| Shales with some sandstone | 75 | 0 |
| Thin coal | | |
| Shale | 8 | 0 |
| Rhengog-fach Seam | 1 | 2 |
| Shale | 77 | 0 |
| Rhengog-fawr Seam with partings | 4 | 0 |
| Underclay | 2 | 6 |
| Coal | 1 | 0 |
| Underclay | 5 | 0 |
| Sandstone | 500 | 0 |
| Cenrhos Seam | 4 | 0 |

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In 1864 an unsuccessful attempt was made to reach the Gyscwm Vein at Elliott's Metal Company's Works, Burry Port, and the following section was proved:—

*Burry Port Trial Pit.*

| | ft. | in. |
|---|---|---|
| Sand [Blown sand] | 28 | 6 |
| Clay | 4 | 6 |
| Gravel [Glacial ?] | 25 | 0 |
| Sandstone with shale | 214 | 11 |
| Coal | 0 | 3 |
| Shale | 26 | 6 |
| Coal | 0 | 5 |
| Shale and clay | 64 | 0 |
| Coal, supposed Clay or Gwdig Vein | 2 | 0 |
| Clay | 1 | 6 |
| Sandstone | 89 | 0 |

The measures dipped northwards at 2 inches to the yard, the pit being situated on the south side of the syncline which underlies Llanelly and Pwll.

In Stanley's Pit (the New Pit of the Six-inch Ordnance Map), the vein was reached and worked under the foreshore down to the bottom of that syncline. The shaft traversed the following section:—

*Stanley's Pit, Pembrey.*

| | ft. | in. |
|---|---|---|
| Superficial deposits [Glacial] | 120 | 0 |
| Sandstone | 144 | 0 |
| Shale | 12 | 0 |
| Coal | 1 | 0 |
| Shale, etc. | 1 | 6 |
| Coal | 1 | 0 |
| Clay, etc. | 6 | 0 |
| Sandstone | 42 | 0 |
| Gyscwm Seam | 3 | 6 |

It will be noticed that the shale which overlies the Gyscwm Seam in Cwm Ierman, and which expands westwards, is replaced here by sandstone, if the description is correct.

A seam supposed to be the Gyscwm is now worked at Craiglon, the section being:—

| | ft. | in. |
|---|---|---|
| Clift | | |
| Rashings | 0 | 6 |
| Coal, in places 3 ft. 6 in., but generally | 2 | 6 |

The level course runs nearly due east and west, so that the crop, if not faulted, will pass under the blown sand and marsh. That tract has not yet been proved.

Turning now to the region lying north of Llanelly we are met with the fact that of the eight easterly downthrows enumerated above, the majority fail to extend so far north as Llannon. On the contrary, nearly all the faults of the N.N.W. system, of which evidence has been obtained in that neighbourhood and north of it, are downthrows to the west.

Mr. Strahan, Mr. Cantrill, and Mr. Dixon.

The Bettws Fault was found by Mr. Cantrill to be obvious in the Red Vein, south of Bettws, and again in the Millstone Grit west of Llandybie. The downthrow is westward, but of unknown amount.

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A downthrow east of 17 yards is said to run under the alluvium between the old Pont-y-clerc colliery and the brick-works. A westerly downthrow was touched at Fairwater from Pant-y-ffynnon old colliery. Mr. Strahan, Mr. Cantrill, and Mr. Dixon.

The Hendre Fault, which runs from the alluvium of the Loughor at Erw-wastad-fach, is a downthrow west, and displaces the crop of the cockshot band at Clawdd-du. Its effects at Hendre will be mentioned on p. 185; northwards, it decreases in throw, and appears to be only 21 yards in the Emlyn workings.

The fault mentioned in the *Summary of Progress* for 1900 (p. 98), as having been proved from Gorseinon and Carn-goch to be a downthrow west of 67 yards, ranges by Bolgoed and the Fountain Inn to near Tal-y-fan. West of the Loughor it passes up Glyn Wallis, and is estimated by Mr. Dixon to have a downthrow west of 200 yards near Pentre-hardd, on the assumption that the coals cropping out at that place are the same as those cropping out at the dingle west of Bryn-bargod. Further north Mr. Cantrill finds it throwing the cockshot at Cefn-gwili. The next fault, which we may name after Bryn-gwili, near Cross Hands, is not known east of the Gwili, but produces a westerly downthrow near Dingle. Its course along the road from Pontardulais to Cross Hands, and its apparently great displacement of the cockshot, will be discussed in connection with the outcrop of that rock. At Cross Hands its effect on the form of the ground, where it separates the soft measures associated with the Big and other veins from the sandstone-ground on its west, makes a part of its course sufficiently obvious, but further north it becomes obscure. It is probably the fault which shifts the Millstone Grit at Craig-y-geifr, and greatly displaces the Limestone at Trawsdre-ganol. Soon after it joins an easterly downthrow, by which it is apparently neutralised.

The Plas-isaf Fault has not proved traceable north of Goitre-wen, but a little to the east of it a fault commences which is exposed in a dingle south of Pant-yr-yn, with a hade to the east. It apparently crosses the Llannon disturbance, described on p. 184, and shifts the successive outcrops as far as Tumble, always with a downthrow east. It may be the fault which neutralises the Bryn-gwili Fault at Trawsdre-ganol.

A fault which passes Gelli-gwernen appears to range for that which throws the Llanelly Four-feet down west at Corn-hwrdd. It is exposed in the left bank of the Morlais near Coed-cyw Mill, where it cuts through some flexures connected with the Llannon disturbance in a manner to suggest that it is of later date. Further north it throws down west a small seam south-west of Pen-y-cwm-uchaf which serves as the base of the Pennant. It cuts through the cockshot at Pen-llwyn-gwyddau, and appears to fall into line with a westerly downthrow, which shifts the Lower Pumpquart Vein of Clôs-isaf and the Carboniferous Limestone at Garn.

The Bryn-serfyll Fault is believed to run along a broad water-logged hollow through the Cockpithall fold, as though it were of later age than the fold, and than the Llannon disturbance, of which the fold forms part.

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Mr. Dixon. In the ground surveyed by Mr. Dixon around Llanedy and Llannon, though there are many local exceptions to the rule, the dip of the strata ranges from S.E. to S.S.E. at an average angle of 15°. Over a considerable tract, however, near Llanedy it is south-west, and there is reason to think that the change is due to a break running east and west almost along a dingle near Gwal-yr-hwch. In the west side of the Gwili Valley and in a line with this dingle there is a hollow from which much water issues, and here also we find an analogous local change of dip. No further evidence, however, of a break has been obtained further west. About two miles further on in that direction the south-westerly curves round to the normal south-easterly dip.

What appears to be a line of overthrust runs south-westwards, close by the east side of Llannon. It gives out much water and the ground east of it is wet and low as compared with that to the west of it. The line thus indicated does not follow the strike, and whereas the strata on its eastern side, as seen in the Morlais, are nearly horizontal, those on its western side undulate sharply. South-west of the Morlais the probable position of the disturbance is suggested by a swampy valley which commences at Nant-garedig. Here the strata on its south-eastern side roll over towards the disturbance, and are even inverted.

Close by and to the west of Nant-garedig, another valley carries us along what seems to be the same line of disturbance, and in about 500 yards we get evidence of overthrusting in the outcrop of a seam worked at Maes-llydan. The seam, as shown by old workings, crops much above the stream on the south-east bank, but appears to lie some depth below it in the north-west bank, the relative positions indicating that the fault must hade to the south-east though its downthrow is north-west.

Here the evidence ceases along the direct line, but a row of springs and an abrupt change of ground suggests that the disturbance continues along a line lying about 150 yards further south. The ground to the north-west of this line of disturbance, including Mynydd Sylen and the neighbourhoods of Cynheidre and Brondini, is characterised by a low dip.

### NORTH CROP.

Mr. Cantrill. The superficial deposits which occupy the Loughor Valley at Ammanford, together with the Bettws Fault, constitute a barrier between the measures on the east and those on the west; new names are adopted for the seams, and at present little has been attempted towards their correlation. The Red Vein, moreover, is unknown west of the Bettws Fault, and is no longer available as a datum-line.

On the west side of the Loughor and as far as Cross Hands the lower measures, which consist chiefly of shales, are thrown into a series of anticlines and synclines having a general direction varying from E.N.E. and W.S.W. to N.E. and S.W. Some of these rolls have a breadth of nearly a mile, but they are generally still farther complicated by sharp folds of only

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a few yards in width. The general nature of the ground is expressed on the old map [41 S.E.], on which the coal-crops were laid down from sources of information no longer available. The anticlines often show dips steeper in the north-west than in the south-east limb. In some cases the folds have passed into thrusts or "overlap-faults" of considerable magnitude; these may be either clean-cut fractures, or narrow belts of highly disturbed ground; but in both cases the thrust makes usually a small angle with the vertical, and the beds above the thrust have moved generally towards the north-west. This disturbed condition of the measures becomes much less severe in the overlying Pennant ground, though there is reason to suspect the presence of more than one sharp belt of compression south of Cross Hands. Mr. Cantrill.

The most important of these thrusts has been brought to light during recent years by the workings at the Park and the Rhôs Collieries, and has been proved to extend from Pontyclerc in a W.S.W. direction along Fferrws Brook past Ty-croes. It separates the Park and the Rhôs Collieries on the north from the Pantyffynnon and the Mynydd-bâch outcrops and workings on the south. Mr. E. R. Fisher* has estimated its effects as equivalent to a downthrow north of about 200 yards. In the slopes of the Ammanford Colliery, which lies a mile farther east, was found a fault which is nearly if not quite in the same line of disturbance. In the opposite or westward direction the thrust ranges for the great tract of unproved ground west of Hendre. A N.N.W. fault with a westerly downthrow, which has been estimated at 90 or 100 yards, has been proved under Myrtle Hill, near Hendre, in the Stanllyd Vein workings of Rhôs Colliery. The Pontyclerc overthrust would intersect this fault about 700 yards south of Hendre, but nothing is known as to either the effect of the intersection or the westerly continuance of the thrust.

By this overthrust the Stanllyd and other veins which crop out at Pontyclerc on the south are repeated, and crop out again to the north near the present Park Colliery. Between the latter and the outcrops in Cwm Lash there is probably another disturbance having the effect of a northerly downthrow ranging E.N.E. through or near Saron. North of this line there seem to be no breaks, but the beds are traversed by repeated rolls which have the effect of giving the outcrops of the coals a complicated sinuous course and carrying them farther and farther north. These undulations are clearly brought out both on the surface by the mapping of the Rock Vein and its overlying massive sandstone, and also underground by the forms of the workings in the Stanllyd and other veins at Blaenau, Pont Lash, Caerbryn, and Emlyn Collieries.

Another overthrust was encountered in the downcast shaft of the New Cross Hands Colliery, where the Lower Pumpquart

* "Remarks on the Mynydd Mawr Anthracite District." October, 1902. 8vo. *Ammanford.*

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Mr. Cantrill. Vein was struck at a depth of 40 yards and again at the bottom of the shaft at a depth of 100 yards. It is believed to range towards the E.N.E. and to separate the Rock Castle workings on the north from those of California and Emlyn on the south.

The principal lower coals west of Ammanford are the following, in descending order :—

| Gorsgôch and west. | Emlyn. | Caerbryn. | Rhôs. | Pantyffynnon. | Pontyclerc. |
|---|---|---|---|---|---|
| Big V. | Big V. | Rock V. | New V. | Upper V. | Rock V. |
| | | Yard V. | Little V. | Little V. | Middle V. |
| Green V. | Green V. | Green V. | U. Pumpquart V. | U. Pumpquart V. | U. Pumpquart V. |
| | Cwmffaldau V. | (?) | Cwmffaldau V. | Coal 1 ft. | Coal 1 ft. 2 in. |
| | Bwla V. | (?) | Bwla V. | [Cwmffalda V.] | Rocket V. |
| Stanllyd V. | Stanllyd V. | Stanllyd V. | Stanllyd V. | Stanllyd V. | Stanllyd V. |
| Gras-uchaf V. | M. Pumpquart V. | M. Pumpquart V. | M. Pumpquart V. | | U. Fireclay V. ? |
| Gras-isaf V. | U. Triquart V. | U. Triquart V. | U. Triquart V. | | L. Fireclay V. ? |
| Charcoal V. | Charcoal V. | Charcoal V. | | | |
| Brasslyd V. | | | | | |
| Gwendraeth V. | | | | | |
| L. Triquart V. | | | | | |
| L. Pumpquart V. | | | | | |
| Rhâs-fach V. | | | | | |

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In this correlation, beside the frequent change of names, the main facts to be noted are the westerly thinning of the ground between the Rock and Middle Veins of Pontyclerc and the ultimate union of these two veins west of Emlyn as the Big Vein. Between the Upper Pumpquart and the Stanllyd Veins are two coals known as the Cwmffaldau and the Bwla; they may be represented at Pontyclerc by the 1ft. 2in. coal and the Rocket Vein respectively, assuming the Stanllyd of Pontyclerc to be rightly named, and the Bwla may be represented by the Green Vein at Pont Lash Colliery. They do not, however, seem to be present at Gors-gôch. Mr. Cantrill.

The Stanllyd appears to be unworkable at Pontyclerc and again west of Cross Hands.

The two Fireclay Veins at Pontyclerc may possibly represent the Middle Pumpquart and the Upper Triquart of Rhôs, etc.

There is much uncertainty as to the correlation of the veins at Tirydail Colliery. Comparing them with the veins below the Upper Triquart at Park and in the Caerbryn district the following seems to be a possible correlation:—

| *Caerbryn, etc.* | *Park.* | *Tirydail.* |
|---|---|---|
| Charcoal V. | Charcoal V. | Supposed Cwmffaldau V. |
| (Brasslyd V.) | Vein 2 ft. 8 in. | Supposed Stanllyd V. |
| (Gwendraeth V.) | Vein 3 ft. 2 in. with clod 1 ft. Vein 1 ft. | Supposed U. Triquart V. |
| L. Triquart V. | Vein 1 ft. Vein 2 ft. | Supposed Charcoal V. 2 ft. 6 in. |
| L. Pumpquart V. | L. Pumpquart V. | L. Pumpquart V. 3 ft. 2 in. Vein 1 ft. 6 in. |

The roof of the Lower Pumpquart Vein at Tirydail agrees with that at Park and at New Cross Hands in containing shells of lamellibranchs.

The foregoing suggested correlation of the veins west of Ammanford appears to bring us no nearer to a comparison of that district with the Amman Valley itself. Two boreholes at Ammanford Colliery, though agreeing fairly well in themselves, are comparable neither with the Pontyclerc section on the west, nor with that of Llwyn-yr-hâf on the east. This last, on the other hand, agrees well with Cwm Amman still farther east. All that can be said of the Ammanford section is that if the vein with numerous partings met with at 170 yards and 241 yards in boreholes No. 1 and No. 2 respectively be the Stanllyd, then the so-called Little Vein now being worked is probably the Brass Vein, and the lowest group of coals found in No. 1 borehole would then represent the Piodau Veins or Little Brass, Middle, and Lower of Brynamman.

Above the Big or Rock Vein, which must not be confounded with the Stanllyd, follows a considerable thickness of shale-ground with occasional beds of sandstone, some resembling cockshot, others Pennant. Here we should expect to find the Red Vein, but it has not been recognised. At the Red Vein workings at Ammanford a clod five feet thick comes in and divides the vein

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Mr. Cantrill. the lower part was worked at the Dynevor and Maes-y-cwarau Colliery as far west as the Bettws Fault, beyond which the vein has never been recognised. It is quite likely that this parting persists westward, and if the coals at the same time deteriorate in quality and thickness, their apparent absence is explained.

At Bettws a well-marked band of cockshot rock lies about 350 feet above the Red Vein. What is probably the same rock crops out west of the Loughor at Buarthau and Pen-yr-heol, south of Ty-croes, and the calculated position of the Red Vein lies somewhere near Penygarn, where some old cropworks occur on the south side of the brook. At Clawdd-du the cockshot is thrown down west by the Hendre Fault and crops out south of Greynor, and the position of the Red Vein would appear to lie somewhere between that place and Plâs-bâch, where some thin coals have been tried in the dingle. At Cefn-Gwili the beds are again thrown down west by what we believe to be the northerly extension of the Gorseinon Fault, and the cockshot crops under the Boulder Clay of the Gwili valley north of Dingle.

West of the Gwili the crop is again thrown north to Gelli'r-odyn-uchaf by the Bryn-gwili Fault which follows the main road from Pontardulais to Cross Hands. It next appears at Pant-gwyn, near Cross Hands, and forms a bold escarpment extending thence south-westwards to beyond Tumble. The Red Vein position would lie probably half-way down this escarpment, and a small vein has been dug along the crop south-west of Llech-y-fedach which may possibly represent it.

It will be noted that the shift of outcrop from Dingle to Gelli'r-odyn-uchaf is about $1\frac{1}{3}$ miles, which indicates a large westerly downthrow. The fault apparently continues northwards to and beyond Pant-gwyn, but does not explain the reappearance of the cockshot on its west side at that place. To account for the repetition we must suppose that between Gelli'r-odyn-uchaf and Pant-gwyn there is a repeating fault—in fact, just such a structure as characterises the Pontyclerc disturbance already described. As will be shown later, the form of the ground near Blaenau-mawr strongly suggests the existence of such a fault, which not improbably is continued as the Llannon disturbance described on p. 184.

Beyond Tumble the cockshot feature is cut through at Pen-llwyn-gwyddau by the Morlais Valley Fault, beyond which it becomes less definite and consequently the position of the Red Vein horizon becomes still more uncertain, but a small vein, said to be one of the Carway Veins, cropping in a dingle above the Llanelly and Mynydd Mawr Railway at Cwm Blawd, may possibly represent it.

The cockshot band forms a well-marked base to a series of alternating shales and Pennant-like sandstone, containing several thin and impersistent coals. The beds are well exposed on the slopes of Mynydd Bettws, and again, west of the Loughor, north of Llanedy and Llannon. These rocks are not distinguishable lithologically from the Pennant series, though for reasons explained elsewhere the Rhondda No. 2 Vein was selected

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in the eastern part of the coalfield as the base of the Pennant. The rocks in question would thus correspond to the Llynfi Rock of the Maesteg district. Mr. Cantrill.

The Garn Swllt Vein on the east of the Loughor near Pantyffynnon is the only representative we can find of the vein which, farther east, on Mynydd Gwrhyd, may with much certainty be regarded as the Ynysarwed or Rhondda No. 2 Vein.* In the district examined during the past year a thin seam occurs in about the right position for that vein, with another seam above it, both having been worked by the farmers at one place or another. The lower seam has been recognised in Llanedy from Gelli-organ to Pentre-hardd, and in the dingle west of Bryn-bargod. In the Gwili valley it is thrown north by the Bryn-gwili Fault, apparently to Ty-gwyn, where a small vein has been worked. Thence the crop trends southwards to near Ty'r-ffynnon, but is soon faulted north again.

Between Ty-gwyn and Llannon there is evidence of lines of disturbance, one ranging S.S.W. past Blaenau-mawr. This makes its appearance in the Gwili river at Cwm-uchaf, three-quarters of a mile below Cross Hands, as a belt of steeply-dipping beds, the strike of which trends thence in a S.S.W. direction along a well-marked hollow to beyond Blaenau-mawr, and separates the shale-ground below the cockshot on the east from the sandstone-ground at Bryn-mawr and Pen-twyn on the west. This latter area is possibly separated by a second disturbance from the long promontory of Twll-y-car and Llwyn-cwta. Around this promontory run two veins exposed at Llwydcoed-fawr. The lower appears to fall in with the calculated position of Rhondda No. 2. The Tumble Fault, an upthrow west, shifts the outcrop to the south, and the coal formerly worked at Pentre is probably one of the two. West of this place the Morlais Valley Fault throws the ground down on the west, and the vein occasionally worked north of Pen-llwyn-uchaf and running thence towards Bryn-gwyn may be the lower of them. It is next seen skirting the west flank of Mynydd Sylen, and is being worked near Farm-fach. The crop passes near Maes-llydan, and comes to the surface in an inlier at Cockpithall, while there are outliers at Cynheidre and Brondini. The Pennant series above this horizon presents the usual characters of dirty sandstone parted by shales which rarely exceed 100 feet in thickness. The coals are used only for local purposes and are of little value.

## SOUTH WALES COALS.

It having been decided that it was desirable to obtain information with respect to the changes undergone by the seams of coals of the South Wales Coalfield, arrangements for the collection of samples were commenced in 1901. The coal varies from house-coal, through an intermediate stage known as steam-coal, to Mr. Strahan.

* Summary of Progress for 1900, *Mem. Geol. Survey*, p. 95; also *Ibid.* for 1901, p. 44.

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Mr. Strahan. anthracite. A large number of analyses had been made, partly in connection with an official report in 1848 by De la Beche and Playfair on "The coals suited to the Steam Navy," partly by public analysts for commercial purposes; but many of these analyses are useless for the present purpose for two reasons, 1st—that the name of the seam is not always given, 2nd—that they have been made by different methods and are not comparable.

The facts reported with respect to the change undergone by the seams are as follows:—

1st. The anthracitic regions lie in the north-western corner of the Carmarthenshire, Brecknock, Glamorganshire field, and in Pembrokeshire. In the former which we may call the main Coalfield, the seams become gradually more bituminous in receding from the anthracitic region. The change takes place from N.E. to S.W. at the west end of the basin; from N. to S. near Swansea; from N.W. to S.E. towards Cardiff; from W. to E. along the North Crop. In other words lines of equal anthracitisation circle round an area, the centre of which must lie between Kidwelly and Llandybie.

2nd. The seams all show the change on approaching the anthracitic region, but the shallower seams show it later. Thus, No. 2 Rhondda Coal keeps its character as a house-coal to within about 25 miles of the anthracitic centre, and then becomes a steam-coal. The lower coals, about 400 yards below, become steam-coals about 30 or 40 miles from the anthracitic centre, and then occur as anthracites for a distance of about 25 miles. In a southerly direction the change from one type of coal to the other is far more rapid, but beyond the fact that the lower seams are highly bituminous in the South Crop and pure anthracites at 12 miles distance in the North Crop, nothing is known.

It will be noticed that in any one deep shaft the upper seams should be more bituminous than the lower. Not only has this been found to be the case, but some of the larger faults are known to throw in bituminous coals in a steam-coal region. From the fact that the anthracitisation is more rapid in a north and south direction it may be inferred that the area of presumed regional metamorphism is elongated in an east and west direction.

There have been many speculations on the cause of the loss of bituminous matter. It has been attributed to the faults, but the evidence produced was unsatisfactory for various reasons.

The analyses were neither sufficiently numerous nor reliable to prove it, while the fact that there are three systems of disturbance, two at least of which differ widely in age and character, was not taken into account. That the anthracitisation was not due to the pre-Triassic disturbances can be proved repeatedly in the South Crop, where the coals, though plicated and vertical, are bituminous. Again, the fact that some of the N.N.W. faults throw bituminous coals against steam-coals indicates that the bituminous matter had been lost before the faults came into

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existence. On the other hand there may be a connection between the anthracitisation and the E.N.E.–W.S.W. system of disturbances. The anthracitic area coincides with the region in which those disturbances are developed, it is elongated in the direction in which the disturbances range, and, lastly, the anthracitisation increases in intensity towards the region of maximum disturbance. Mr. Strahan.

It has been suggested also that the anthracitisation has been brought about by heat, and that the heat was due to the coals of the anthracitic regions having been more deeply buried than other parts of the Coal Fields. Stratigraphical evidence, on the contrary, points to the bituminous regions having been the more deeply buried, both under later Carboniferous and Secondary Rocks.

The principal objects for which the series of analyses now in progress is wanted are:—

For the purpose of drawing lines of iso-anthracism for each of the principal seams, and of defining the areas occupied by house-coal, steam coal, and anthracite, in the unproved parts of the Coal Field. This is a matter of the greatest economic importance.

Of investigating the possible connection of the loss of volatile matter with any of the systems of faulting or folding.

Of forecasting whether the upper seams in the "steam-coal condition" may be expected to be of the same value as the lower coals which are now worked as steam-coals in the Rhondda Valleys.

Arrangements were commenced for the collecting of "Samples of Coal" in January, 1901. The advice of the South Wales Institute of Engineers had been sought, with the result that a Committee was formed of gentlemen representative of every part of the Coal Field, who undertook to communicate with the colliery-proprietors and seek their consent to the collecting and analysing samples of their coal. It was arranged that the analyses should be published, but that the localities from which the samples were obtained should be indicated by numbers only on a general map of the Coal Field, and that the names of the collieries should not be mentioned.

The first collection of coals was made in 1901. It was arranged that the collector should be conducted at every colliery to a working face, where a typical development of the seam was exhibited, and that coal should be cut by a colliery-official from all parts of the face, except those partings which are separated out by the miners. The coal thus cut was sampled by the collector in the usual manner and enclosed in a box with a printed form filled in by the colliery-manager, on which were given the name and section of the seam, depth from surface, and other particulars. Eleven samples were collected in 1901, and a second collection of ten samples was made in 1902. Among these samples the three principal varieties of coal are represented, namely, bituminous house-coals, steam-coals, and anthracite. Ten samples from the first collection have been analysed. The method of analysis is discussed by Dr. Pollard in the *Summary of Progress for 1901*, pp. 72–80.

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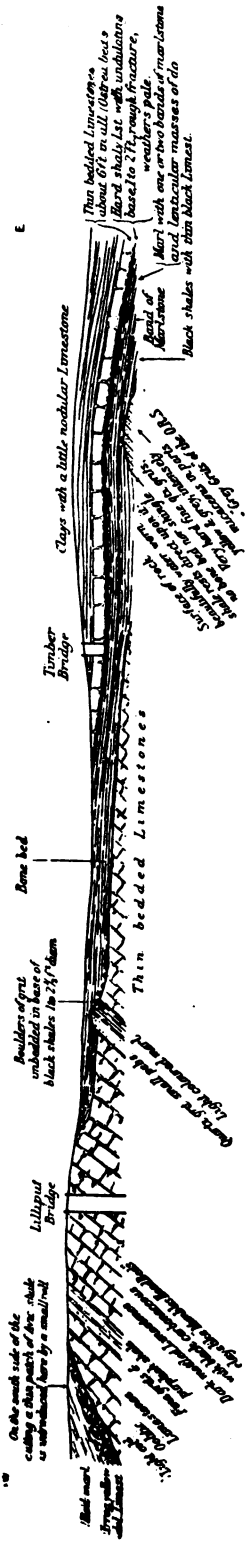
Thin bedded Limestones
Timber Bridge
Lilliput Bridge
Bone bed
Clays with a little nodular Limestone
Boulders of grit imbedded in base of black shales, up to 2½ ft. thick
Thin bedded limestones about 6½ in all (Watts bed)
Hard shaly 1st with undulating base 1 to 2½, rough fracture, weather's pale
Marl with one or two bands of marl-stone and lenticular masses of do
Bands of Marl-stone
Black shales with thin black limest.

FIG. 9.—*Railway-cutting near Chipping Sodbury.*

## V.—CUTTING ON THE SOUTH WALES DIRECT RAILWAY, NEAR CHIPPING SODBURY.

BY A. STRAHAN, M.A.

By the courtesy of Mr. B. A. Baker, the Directors' attention was called to the further opening of the new section in the South Wales Direct Railway near Chipping Sodbury, previously reported on by Messrs. Woodward and Strahan,* and the section was re-visited in July.

The cutting traverses a ridge of Carboniferous Limestone which projects through the Secondary Rocks. It discloses the history of the gradual submerging of the ridge under Triassic and Liassic waters.

On the west side of the ridge Keuper Marl, with irregular deposits of yellow dolomitic limestone, rests directly upon the limestone. Its thickness, however, was not great, for a small roll down to the west suffices to bring in some of the over-lying *Avicula contorta*-shales on the south side of the cutting. The marl, dipping westwards, ends off about 200 yards west of Lilliput Bridge, and the cutting then shows Carboniferous Limestone up to the surface as far as, and a few yards east of, the bridge. About 20 or 30 yards east of Lilliput Bridge the *Avicula contorta*-shales come in again, but this time without any Keuper Marl intervening between them and the Carboniferous Limestone; nor indeed does the marl occur anywhere in the cutting east of the bridge. The shales, slanting gently down eastwards with what is as likely to be a slope of deposition as a dip produced by subsequent movement, rest upon a remarkably smooth and even floor cut out from the highly inclined Carboniferous Limestone. In one place only a hard grit, interbedded in the limestone, projects above the general level, and it is interesting to note that for a short time the crag formed a small Rhætic island from which blocks of grit rolled down into the earliest Rhætic

* Summary of Progress for 1898, p. 191.
There is a brief reference to this cutting in a paper by Messrs. S. H. Reynolds and A. Vaughan, *Quart. Geol. Soc.*, vol. lviii., p. 727 (1902).

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sediments. Before the close of the Rhætic period the crag was submerged and its site smoothed over by the uppermost bands of shale. Two hundred yards east of it there is a small pocket showing the Rhætic Bone-bed in characteristic form.

The Lias commences 400 yards east of Lilliput Bridge, and the cutting then yields the following measurements:—

| | | ft. | in. |
|---|---|---|---|
| Lower Lias | Shale with a thin limestone, seen to | 40 | 0 |
| | Thin bedded limestone with shale-partings (*Ostrea*-beds) | 6 | 0 |
| Rhætic Beds | Hard limestone with undulating base; rough shelly fracture; weathers pale* | 2 | 0 |
| | Pale-blue shaly marl, 1 ft. to 5 ft. | 6 | 0 |
| | Pale-coloured marl-stone | 1 | 0 |
| | Very pale marl, containing masses of harder marl-stone | 6 | 0 |
| | Shale, darker | 1 | 0 |
| | Dark limestone and "bref" | 0 | 3 |
| | Dark shale with *Avicula contorta* | 8 | 0 |
| | Carboniferous Limestone | — | |

These various bands and especially the hard limestone with undulating base can be traced along the sides of the cutting eastwards, that rock finally sinking to the level of the rails 800 yards east of Lilliput Bridge. A slight undulation, however, was apparent at a point 150 yards short of its disappearance, which might have suggested a gentle anticline, had not the bottom of the cutting revealed the true cause. The undulation marks the site of a submerged crag formed by a fine-grained but extremely hard quartz-grit, yellow and grey in colour and intensely micaceous. Like the crag previously referred to, this rock formed an island temporarily in the Rhætic water, but was submerged and buried before the Rhætic period closed. Its surface still shows the effect of Rhætic waves. Though there are no shingle or boulders, its outlines are beautifully water-worn. The rock obviously belongs to the Old Red Sandstone, and without much doubt to the uppermost subdivision of it.

Retracing our steps we may note the sequence in these older rocks. They dip uniformly westwards at about 40°. Between the crag of Old Red Sandstone and the nearest exposed limestone (as shown in July) there is a gap of about 150 yards, in which presumably there would be found a natural junction between the two formations. For about 300 yards the cutting then traverses thin-bedded limestones, and reaches a light-coloured marl overlain by a quartz-grit with small pebbles which forms the crag first described. On the west side of Lilliput Bridge there occur, still in ascending order, dark mottled limestone with black carbonaceous beds, which recall the Mumbles Head Beds of Gower,† and then fine grit and purplish shale, followed by light-coloured oolitic limestones. Here we lose sight of the older

* Messrs. Reynolds & Vaughan note here the Sun-bed and underlying Cotham Marble.

† Summary of Progress for 1901, p. 41.



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rocks under Keuper Marl, but from the fact that shales occur west of Chipping Sodbury nearly on the line of strike of the limestone last seen, we may assume that we are not far from the top of the formation. The shales referred to have been disclosed in working pockets and veins of "strontian." Its occurrence in rock of Carboniferous age is doubtless due to the fact that the Keuper Marl lay immediately overhead, The mineral is found down to a depth of not more than 6 or 8 feet.

The absence of the Keuper Marl in the eastern part of this section suggests a difficulty. It may be assumed that the areas where the *Avicula contorta*-shales rest directly upon the old rocks were above water during Keuper times; that is to say, the eastern part of the section must have stood higher relatively to the western part than it does now. But the Keuper Marl already has a strong westerly dip. The raising of the eastern part of the section involves an increase in this dip. Had the material been breccia the dip might have been attributed to "slope of deposition," but it hardly seems probable that marl and limestone could be lain down in strata so far from horizontal. A fault with a downthrow east would explain the circumstances, but no such fault has been detected.

## VI. The Woodford and Ilford Railway.

BY J. ALLEN HOWE, B.Sc., F.G.S.

This new line leaves the G. E. Main Line opposite the Ilford cemetery and continues in a northward direction as far as Grange Hill where it bends sharply to the west for Woodford. The shallow cutting north of Cauliflower Lane, shows a thin covering of loam, 2 to 3 feet, on gravel; for 200 yards north and south of Ward's Lane the loam is absent, only gravel, with sand-layers, being present. At a point some 300 yards south of Hatch Lane Station (for Ley Street) the cutting passes through the thin strip of gravel-covered London Clay, which here separates the lower from the higher terrace. From the Station to the stream north of Ley Street is a good section in the high terrace gravel; near the School there is a thickness of about 15 to 20 feet of gravel upon 8 to 10 feet of London Clay with septaria. The gravel maintains its thickness to the north end of the cutting but rapidly thins southward, till at the Station it has almost disappeared. Across the broad gravel terrace of Fairlop Plain there are no exposures; the line leaves the gravel and enters the London Clay of the rising ground about half a mile south of Manor Road Station. In the tunnel of Grange Hill, and the deep cutting under Hainault Road, London Clay alone is exposed; except that there is a sprinkling here and there of gravel-wash from the higher ground of Tom's Hill.

A short account of the geology of the line has been written by Mr. T. V. Holmes, F.G.S.*

* *Essex Naturalist*, vol. xii., pp. 202–206.

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## VII. Notes on the Occurrence of Natural Gas at Heathfield, Sussex.

By H. B. WOODWARD, F.R.S.

In a paper read before the Geological Society of London in 1898, Mr. Charles Dawson directed attention to the discovery of Natural Gas in East Sussex.*

Referring first to the reported issue of inflammable gas in the deep boring made at Netherfield, near Mountfield, for the Sub-Wealden Exploration, and which was (1875) attributed to the petroleum-bearing Kimeridge Clay, Mr. Dawson then gives particulars of the discovery of natural gas at Heathfield.

In 1895, when a boring was made in search of water at Heathfield Hotel, the foreman of the work found that inflammable gas was being given off at a depth of 228 feet. No special interest appears at the time to have been taken in this discovery, and as no supply of water was obtained the boring was abandoned.

In the following year another boring for water was made by the London, Brighton, and South Coast Railway Company, by the side of the railway between Heathfield Station and the tunnel to the north-west. This boring was abandoned at the depth of 377 feet, as "no useful amount of water" was obtained. At the depth of 312 feet there was, however, a rush of gas so pronounced that it was tested, and a flame of about 16 feet in height was the result. A strong odour of gas had been noticed at lesser depths, and below 312 feet it "continued to increase during the remainder of the depth bored." No immediate steps were taken to utilise the gas, indeed the wrought-iron tubes were withdrawn from the borehole, with the exception of about one-length which was left in the ground.

Experiments made in 1898 having proved that the quality of the gas was suitable, and that the pressure and supply were maintained, the gas was in 1899 utilised in lighting up the railway station and subsequently for other purposes.

The possible importance of the gas-field did not, however, arouse public interest until the present year when the company entitled "The Natural Gas Fields of England, Limited," commenced a series of borings at Heathfield and at Mayfield. As a result, the village of Heathfield has been lighted from one of the bore-holes, and pipes have been laid down for the supply of Polegate and Eastbourne.

Five borings have now been made or are in progress between Heathfield Station and Britannia Mill, and a sixth is in progress by the eastern side of Waldron Gill, rather less than half a mile south of the station. Through the courtesy of Mr. Inverness Watts, engineer to the company, I was enabled to visit the sites. Gas had been found in all but one (No. 5) of the bore-holes. Unfortunately the borings are made by means of a "jumper" and the material is brought up as sludge, mostly a silty clay, so

* *Quart Journ. Geol. Soc.*, vol. liv. p. 564 ; and *Proc. Geol. Assoc.*, vol. xvii. 1901, p. 171.



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that details of the strata cannot be ascertained and recorded with anything like the precision that was possible with the cores from the two earlier borings, made by Messrs. Le Grand and Sutcliff. On those borings we must rely chiefly for our knowledge of the strata.

Summarised, the particulars are as follows*:—

| | Heathfield Hotel 493 feet above OD. | Feet. Thickness. | Depth. |
|---|---|---|---|
| Ashdown Sand. | Sand with lignite and marl (Dug Well) | 21 | 21 |
| | Sandstone and marl | 11 | 32 |
| | Sandstone | 18 | 50 |
| | Sandstone and marl | 21 | 71 |
| | Sandstone | 5 | 76 |
| | Sandstone and marl | 18 | 94 |
| | Marl | 57 | 151 |
| | Sand-rock | 4½ | 155½ |
| | Marl with stone-band | 60½ | 216 |
| | Sand-rock | 3 | 219 |
| | Marl | 30 | 249 |

*Gas noticed at 228 feet.*

| | Heathfield Station 450 feet above OD. | Feet. Thickness. | Depth. |
|---|---|---|---|
| Fairlight Clays and Ashdown Sand. | Dug Well | 73 | 73 |
| | Sandy marl-rock, lignite and ironstone | 67 | 140 |
| | Hard sandstone | 1¾ | 141¾ |
| | Sandy marl-rock, ironstone | 19¾ | 161½ |
| | Sandstone | 1¼ | 162¾ |
| | Marl - rock, sandstone and ironstone | 9¼ | 172 |
| | Sandy marl-rock and ironstone bands | 24¼ | 196¼ |
| | Marl and sandstone | 22¾ | 219 |
| | Sandy marl-rock and sandstone | 45½ | 264½ |
| Purbeck Beds. | Marl with bands of marble | 2½ | 267 |
| | Marl and shale and marl rock (*Paludina*) | 72 | 339 |
| | Marl-rock, bituminous shale, shells | 14 | 353 |
| | Marl, shale and shell-rock | 24 | 377 |

*Gas first lighted at 312 feet.*

Mr. I. Watts informed me that in the new borings gas is found to issue at about 280 feet, sometimes when hard iron-stone bands are pierced. The pressure at Heathfield Station was stated to be equal to 200 lbs. to the square inch, and this had not been modified by the subsequent borings. The quality is so good that no refining is necessary.

Heathfield Station is in Waldron Parish, and the newer part of the village of Heathfield extends to the north-east and south-east of the station, at the head of a fine valley which opens out to the south-west and is drained by Waldron Gill. The ground rises on the north to 600 feet near Mutton Hall, and to the south to 598 feet at Gibraltar Tower in Heathfield Park. These higher and well-wooded grounds are formed mainly of sandstones which dip northwards (as shown on the Geological Survey Map) on the north, while in Heathfield Park the beds are inclined to the south-east. Thus the anticline which brings in the Purbeck

* Dawson, *op. cit.*, pp. 569-571. See also Water Supply of Sussex, *Geol. Survey*, pp. 87-89.

Mr. Whitaker has grouped all the beds at Heathfield Station down to 339 feet with the Fairlight clays.

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beds further east along the course of the River Dudwell, probably extends in a north-westerly direction through Tilsmore Wood; and Heathfield Station would be on the southern side of the anticline, with perhaps an inlier of Lower Wealden (Fairlight) clays and sands in the Waldron Gill valley to the south-east.

The district may be affected by more faults than are shown on the Geological Survey Map, but if the dip, as above stated, is maintained, it is probable that all the six borings have been commenced in approximately the same strata—perhaps No. 5 in slightly higher and No. 6 in slightly lower strata than those of the four other borings.

The strata exposed in the banks of Waldron Gill, below the site of No. 6 Boring, comprise thin-bedded sandstones with harder bands of ferruginous sandstone, and these are bent in one spot into a sharp fold. Lignite has been dug in the bed of this brook. *

In general the beds here comprise sandstone, fine sand, lignitic sands, white sandy clay and purplish clay. The brickyard south of Heathfield Station exposed whitish clay and sands in thin alternating beds.

In the two quarries in the north-west of Heathfield Park, 12 to 15 feet of thin fissile sandstones, with bands of pale purplish and whitish clay, overlie thick-bedded sandstone much jointed and also false-bedded. The soil made up of the alternating fine sands and clays is impermeable in places, so that water stands here and there in pools in wet weather, and the roads are wet and silty. The thick-bedded sandstones above noted would be well adapted to store gas under favourable circumstances. They are, however, above the horizon of the strata penetrated in the Heathfield borings.

Beds on the horizon of those bored into at Heathfield are exposed on the borders of the deep valley east of Heathfield Park, where also the Purbeck Beds come to the surface, at a distance of rather less than two miles from Heathfield Station. North of Punnett's Town, to the east of Cade Street, ferruginous sandstone and loam and fine-grained sands and sandstones are observable on the way from Lucks' Farm to Little Greenwood.

Further on to the east of Greenwood Farm purple and mottled clays are exposed, while south of the Ford on the River Dudwell, on the trackway from Three Cups Corner to Pounceford or Poundsford, there may be noted in descending order:—

| | |
|---|---|
| Wealden— | Yellow sandstones and clayey beds. |
| (Fairlight Clays) | Grey and purplish clay. |
| Purbeck | Leathery shales. |

On the north side of the Ford, Purbeck Beds were shown having a high northerly dip, but there is little doubt that the beds are disturbed by landslipping. Shelly limestone and shale

* See Topley, Geology of the Weald, pp. 347, 348.

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and compact limestone here occur, and higher up leathery shales like those seen south of the river. The intermediate ground has cappings of grey and ferruginous clay with blocks of Wealden sandstone, suggestive of a southerly dip, and of the crest of the anticline being a little north of the Dudwell, an inference supported by dips marked on the Geological Survey Map.

On the hill above Poundsford the beds have a northerly dip, and the section is like that of the quarries in Heathfield Park. Fine white sand, sandy clay and ferruginous sandstone in thin layers, overlie thick beds (3 or 4 feet) of yellow sandstone, much jointed. These beds appear to be slightly faulted, but are more probably displaced by landslip on the brow of the hill. The bold features north of Poundsford are formed by the strong beds of sandstone, and had there not been considerable faulting and downthrow of Wadhurst clay and Tunbridge Wells sands, the Purbeck Beds might again have appeared further north in the valley of the Rother. As it is Mayfield, where another boring is being made, is on Tunbridge Wells sands and sandstone. These are much more evenly bedded than the Ashdown sands of Heathfield, but they also have sandy clay partings.

The leathery shales which occur in the upper part of the Purbeck Beds at Poundsford are distinctly bituminous. Specimens have been tested by Dr. Pollard.

Attention however was directed to this fact by Topley, who stated in 1875 that Mr. R. Hallett, then owner of Swife's Farm, near Burwash "had several tons operated upon, from which was extracted in the first instance tar, and by subsequent processes a variety of products such as pitch, grease, oil, naphtha, and paraffin."*

Topley also called my attention to the fact that the gypsum at the works at Netherfield becomes bituminous along a line of fault.†

Again, in the Kimeridge Clay at the Sub-Wealden Boring, a "hard light-coloured bed, very rich in petroleum" was passed through at depths of 600 to 602 feet,‡ and bituminous shales again occurred from 960 to 1000 feet.

The information which is before us indicates that a certain amount of natural gas is pent up in the Lower Wealden Beds and in the Purbeck Beds. The bore-holes, however, have not penetrated any thick masses of porous strata such as we might judge capable of storing a vast accumulation of gas. What has been obtained must have been stored in comparatively thin layers of sandstone and sand interlaminated with the Wealden clays, and in the harder bands of the Purbeck.

It appears, therefore, that gas is derived from Purbeck shales and that it may be stored over a considerable area in the thin porous beds. The Portland Beds identified in the sub-Wealden Boring have been somewhat differently described in the several

* Geology of The Weald, p. 38.

† Jurassic Rocks of Britain, vol. v., p. 331.

‡ Geology of the Weald, p. 43.

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records which have been published. That given by Topley in Dixon's Geology of Sussex* is noted in the accompanying general table.

General Section of the strata in the Heathfield District.

| | | Feet. |
|---|---|---|
| Ashdown Sand with Fairlight Clays 350 to 400 feet. | Sands, sandstones, loamy sands, shales, and clays —on the whole more clayey towards the base (= Fairlight Clays) | |
| Purbeck Beds 400 feet. | Shales, etc. | 30 |
| | Limestones, calcareous sandstones and shales | 50 |
| | Shales and clays with occasional stone-beds | 130 |
| | Limestones and shales | 75 |
| | Shales with occasional stone-beds | 35 |
| | Shales with gypsum | 80 |
| Portland Beds 115 feet. | Sandy shale | 23 |
| | Soft whitish sandstone | 52 |
| | Darker sandstone | 5 |
| | Sandy shale | 35 |
| Kimeridge Clay 1273 feet. | Shales with septaria, etc. | 668 |
| | Bituminous shales | 40 |
| | Clays and sandy beds | 4 |
| | Sandstone | 41 |
| | Sandy shale, etc. | 47 |
| | Shaly sandstone | 45 |
| | Limestone | 45 |
| | Shale | 94 |
| | Limestone | 29 |
| | Shale | 20 |
| | Grit and limestone | 45 |
| | Limestone and shale | 27 |
| | Shale | 23 |
| | Limestone | 10 |
| | Shale | 135 |

Here, below the Purbeck Beds, we have evidence of important beds of sand and sandstone 50 to 60 feet in thickness, and capable of storing a great quantity of gas.

At present these strata have not been penetrated in any of the bore-holes in search of natural gas, and it would seem necessary to bore from 300 to 320 feet deeper at Heathfield to reach this horizon.

It is possible, however, that gas from these Portland Beds may have been indirectly tapped through crevices and fault-planes, but on this point nothing definite can be said.

The absence of water from the strata may be due to the presence of the gas, and water may replace it as it escapes.

## VIII.—On the Drifts of the Thames Valley near London.

By T. I. Pocock, M.A.

The drifts of the area surveyed in the past year consist of Boulder Clay, gravel sand, brickearth, and alluvium of various ages from the climax of the Glacial period to recent times.

* Ed. 2, p. 154, see also pp. xxiii. and 6 ; H. B. Woodward, Jurassic Rocks of Britain, vol. v., p. 229 ; Water Supply of Sussex, pp. 65–70. The boring is at Mountfield.

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These deposits will be described as far as possible in the order of their age.

The oldest of the drifts is the Boulder Clay with some associated beds of brickearth, which are found near Upminster, in Essex. They occupy a very small area but are of great interest as showing the relation of the Thames valley to the Glacial period. The best section to be seen is at some brick and tile works a mile and a half north of Upminster Railway Station.* The brickearth is worked in two pits, one on each side of the lane which runs eastwards from "Martins" Farm (v. one-inch map). The pit on the south side of the lane shows about 20 feet of brickearth with a few seams of small gravel. It is sandy and finely laminated in the lower part, but tough and more homogeneous above. It is evidently a water-formed deposit, but the occasional contortion of the laminæ seems to indicate disturbance by ice-floes. The brickearth thins away suddenly on the west side of the workings, and Boulder Clay rises from beneath it. In some shallow, almost overgrown pits nearer the main road there is a section of clay 2 or 3 feet thick containing abundant unworn flints and pieces of chalk together with quartzite pebbles and subangular blocks of sandstone, some of which are smoothed and striated. The base of the Boulder Clay is no longer exposed, but according to the information of the foreman of the brick works, the chalky clay rests upon a variable bed of sand a few feet thick, under which is a tough clay full of stones but containing no chalk.

In the working on the north side of the lane the Boulder Clay is wanting. The brickearth is about 15 feet thick and rests directly on London Clay. On all sides except the west the brickearth has been cut round by denudation so that its original extent is uncertain. It is probably an older deposit than the great mass of brickearth at a lower level in the Thames valley, indeed, its association with Boulder Clay suggests that it is part of an old glacial lake deposit. No organic remains have as yet been found to confirm this view. The level of the Boulder Clay at this point is about 150 feet above ordnance datum. Several outliers of stony clay have been traced in this neighbourhood, some of which still contain a little chalk, and others are probably decalcified remnants of the chalky Boulder Clay. They are found on both sides of the Ingrebourne brook from 50 to 100 feet above the bottom of the valley, and gradually increase in elevation as they are traced northwards. Doubtless they are the remnants of a continuous bed of Boulder Clay, which stretched from the high ground separating the valleys of the Roding and the Ingrebourne southwards into the Thames valley. The lowest point at which the Boulder Clay has been found is in the railway cutting between Romford and Upminster

* See Whitaker, Geology of London, Vol. i., 1889, p. 415. The pits with Boulder Clay have been opened in recent years and seem not to have been previously described.

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where it descends beneath the river gravel at about 80 feet above sea level.*

Hence we are led to the conclusion that the greater features of the Thames valley were formed before the climax of the Ice Age. The bottom of the main valley in Essex was no more than 80 feet above the present sea-level, and the broader tributary valleys had already been carved out. It is known that the Boulder Clay reaches the summits of the hills near Brentwood,† but is absent from the Warley hills, which rise to a less elevation between Brentwood and the Thames valley. It is doubtful whether the ice crossed these hills and descended *en masse* into the river valley. The small quantity of Boulder Clay, which is restricted to the lower slopes, would rather indicate that the ice sheet was broken up into branches, one of which pushed its way glacier-like through the open valley west of Warley, and perhaps came to an end at the ancient margin of the Thames.

What was the extreme limit of the ice has not been ascertained. There are some indications of Boulder Clay at North Ockendon, but no section could be found to prove that it is actually there. It may be that the Thames valley was still further cut down in pre-glacial time, and was filled up again subsequently by deposits of gravel. But there can be no doubt that much denudation of the Cretaceous and Tertiary formations, as well as of the gravels, was effected by the Thames and its tributaries long after the dissolution of the ice sheet.

The next series of deposits which have to be described are the Gravel Drifts. Their character is well known from the writings of many geologists, and it will suffice to state briefly that they consist of masses of subangular flint with a varying admixture of pebbles derived from the Tertiary formations, and a few igneous and sedimentary blocks from distant localities. Occasionally large boulders are found in them. Intercalations of sand are frequent and the deposits are on the whole stratified, though the bedding is often much confused.

The oldest of the gravels, which has been examined in the past year, covers some of the lower plateaux west of the metropolis.

The Boulder Clay of the south-eastern counties is frequently underlaid by beds of sand and gravel, and beyond the limit of the Boulder Clay itself, wide tracts at a considerable elevation are covered by like deposits of approximately the same age. These gravels show clearly the action of water, and they are not essentially different from the gravels at lower levels which are confined to the river valley. Whatever is the cause of the one is in some measure the cause of the others. But the wide extent of these plateau gravels shows that they could not have been formed by rivers confined to their valleys. They

* T. V. Holmes, *Essex Naturalist*, vol. vii., Nos.1-3.

† H. B Woodward in Whitaker's Geology of London, vol. i., p. 325 ; see also Prestwich, *Quart. Journ. Geol. Soc.*, vol. xlvi. Pl. vii. Fig. 5.

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are comparable to the broad tracts of fluvioglacial gravel which spread northwards from the external moraines of the old Alpine glaciers. The normal drainage of the Thames valley was obliterated, and the tumultuous waters which escaped from the edge of the ice sheet, combined with the streams which flowed from the snow-clad hills to the south, overspread the country far above the level of the preglacial river. The surface on which the fluvioglacial gravels rest is an uneven one. In some cases they pass down the slopes so far that it is impossible to separate them from the valley gravel of the upper terrace. Thus, in the neighbourhood of Hillingdon, Mr. Howe found that the gravel rises apparently without intermission or break from about the 100-foot contour to 190 feet in the village.

The gravel on Uxbridge Common lies at an elevation of 205 feet and a little farther north at Harefield it reaches 222 feet. At Iver the same conditions obtain; the gravels in the village at 130 feet extend downwards, beneath the brickearth, to the 100-foot contour, and upwards towards Iver Heath at 176 feet and beyond. Again at Wimbledon Common (180 feet) the lower part of the hill consists of London Clay capped by a small outlier of Bagshot sand. The plateau itself consists of gravel which not only completely covers the Bagshot outlier but extends for some distance down the slopes of the London Clay. A similar disposition of the gravel has been noticed by Mr. Spurrell on the south bank of the river in Kent.

Enough has now been said to show that the Thames basin had been deeply eroded before the deposition of the plateau gravel which has just been described, and that its elevated position is due to a subsequent rise of the water to that level during the glacial period. No gravel corresponding to the fluvioglacial gravels of Middlesex has been found on the Essex side of the Thames as far east as the survey has been carried. Probably none was deposited there because much of that region was occupied by the ice sheet itself. By the time the ice had been washed away the waters had sunk and were accumulating gravels at a lower level.

The gravels of later date can be divided into three terraces, which can be traced all over the ground, though they are much less distinctly separated in some parts than in others. In character the later gravels are essentially the same as the fluvioglacial gravels, but they differ in being confined to the limits of the river valley. It is doubtful, however, whether this distinction will hold good when the terraces are traced eastwards along the estuary of the Thames. The terraces will for convenience be described as upper, middle and lower.

The upper terrace is poorly represented in the part of our area which lies east of Hornchurch. But small outliers are found resting on the Chalk at Grays and on the London Clay at Aveley. The same gravel apparently rises from beneath the brickearth near North Ockendon. But from Hornchurch westwards the terrace can be traced along the slopes of the Thames valley as far as Uxbridge and beyond, though there are large

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gaps where the tributary streams have cut it away. On the south side of the river it occurs as small outliers near Chertsey, Weybridge, Richmond and at various spots in the north of Kent. The channel in which this ancient gravel was deposited, is about seven miles broad in Essex between the Laindon Hills and London. Between Westminster and Richmond it is reduced to less than five miles, but it expands again westwards till it reaches a maximum of fully 10 miles in a north and south line through Southall. Still further west the breadth decreases till it is only about a mile at Cookham.

Throughout the forty miles from Staines to Grays, the upper terrace maintains the same average height above the sea level. Its under surface vàries from place to place, but generally speaking it is at about the 100-foot contour line near its margin. Towards the centre of the old channel, as at Brentford and North Ockendon it descends to a lower level. But no general inclination of the terrace can be traced as it is followed down the valley towards the sea. On the other hand there is a slight fall in level between Maidenhead and Staines. Hence we may conclude that the inland portion of the old river ended somewhere between these two places, and that for the rest of its course it flowed at the sea level, like the tidal part of the modern Thames, or else that it formed a broad lake-like expansion, which was held in by a barrier separating it from the open sea. If the upper terrace were extended along the valley into Eastern Essex. it would pass into an extensive gravel deposit in the neighbourhood of Colchester which is of glacial age, since it can be traced under the Boulder Clay. It is not improbable that the two are equivalent, and that while the 100-foot terrace was forming in the Thames valley, the ice still lingered in Eastern Essex, though it had disappeared from the immediate neighbourhood of London. The difficulty of separating the fluvioglacial gravels from the upper terrace has already been mentioned. Probably the deposition of gravel was continuous in some localities, while at others considerable erosion took place between the formation of the two deposits.

After the formation of the upper terrace there ensued an epoch of river erosion, during which the valley was cut down to the extent of 40 feet or more. The upper terrace was broken up, and the underlying formations in many places exposed at the surface. Whether any of the superficial deposits belong to this epoch of erosion it is not easy to say. No fluviatile gravel can with certainty be assigned to it, but possibly some of the brickearth deposits which overlie the upper terrace may have been formed on the valley slopes when the river was cutting its way through the gravel. Be this as it may, after the erosion had lowered the valley to 40 or 50 feet above the present sea level, another epoch of gravel accumulation began. This deposit is of the same character as the upper terrace, but is confined to much narrower limits. Here and there it contains thin beds of sand and loam, which are much disturbed, perhaps by the action of ground ice. In one section at Hampton, where the gravel has

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been cut through, the London clay underneath seems to have been ploughed up by the same agency. But such phenomena are less conspicuous than in the upper terrace. The middle terrace forms a broad expanse on the north side of the Thames in Essex, and again between Brentford and the Colne, but it is much less extensive on the south side of the river. Often there is no middle terrace between the upper and lower. As in the case of the higher formation, the 50-foot gravel occupies the same average level in Essex as it does in Middlesex, but at Maidenhead it is considerably higher. North of Purfleet and Grays it follows very nearly the 50-foot contour. In the tributary streams further west the underlying London Clay can generally be seen rising gradually from south to north to a little over 50 feet. Near Isleworth and Hampton the London Clay has been exposed by denudation in several places at a level rather below 50 feet, and again at the northern end of the Staines reservoir the London Clay was touched at nearly the same level. During the formation of this gravel, the river flowed to the north of the chalk ridge, which extends from Purfleet to Grays, and probably the present channel to the south of that area had not been excavated. But elsewhere the river followed its present course, though it was much wider than the modern Thames. The inland portion of the river probably extended further east than at the time of the 100 foot terrace. But between Staines and Grays a uniform level was maintained, which, as in the former case, may have been the sea level of the time. Whether the terrace can be traced round the coast into fluvioglacial gravels has not been ascertained. Yet its character shows that it is a deposit of the same kind—that is to say, it owes its origin to the floods which resulted from the melting of accumulated snows on the hills.

After the formation of the 50 foot terrace there followed a second epoch of valley erosion. The gravel flats were left bare, and the river, flowing in a narrower channel, gradually cut down its bed to a level not far above the present high water mark. It is to this period that the greater part of the brickearth of the Thames valley belongs. It covers a large part of the middle terrace between Upminster and South Ockendon, and extends beyond the limits of the gravel on to the London Clay. In Middlesex it is more strongly developed, and covers indifferently all the three terraces. Prestwich long ago compared the brickearth to the Löss of the Rhine Valley* and other parts of Central Europe. Like that deposit it owes its origin to different agencies and probably also to varying conditions of climate and geography extending over a considerable space of time. Moreover, it belongs to more than one distinct epoch. Some of the deposits may be older than the middle terrace, as has been seen already. Others are younger than the later terrace for they form thin sheets covering the lowest gravel near the river in Middlesex, and probably pass up the slopes over the

* *Phil. Trans.* 1864.

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older brickearths. Sections of this later brickearth can be seen near Shepperton Railway Station and at the Brick Works, Upper Halliford. At the same time the greater part of the Brick-earth is older than the lower terrace, as is clearly seen in the sections at Grays, and in that at Crayford described by Mr. Spurrell.* Like the European Löss the brickearths may be distinguished as stratified and unstratified. The former type consists of finely bedded sands and loams, and contains a fresh-water fauna, which indicates a temperate climate. It is due to the overflow of the river, but the floods resembled those which take place at the present day rather than the tumultuous waters of an ice age. The other type of brickearth is an unstratified red loam, which owes its origin to the break up of the land surface by subaerial agencies and the redistribution of the loose material partly by wind and partly by the wash of rain-water on the valley slopes. These two types of brickearth are not separated in point of time, but probably alternate with one another. There were several breaks in the continuity of their formation, as is shown by the occurrence of land surfaces with palaeolithic "workshops," but the stratigraphical significance of these breaks has not been clearly made out. The unstratified type of brickearth is very widely distributed in the Thames valley, though in many places it is a very thin deposit. It has been observed from the lowest levels near the river up to the tops of the highest terraces, and the greater part of the brickearth which is shown on the map is of this type.

After the formation of the main mass of the brick-earth, a third terrace of gravel was deposited which is lower and less extensive than either of the other two. During the interval between the epochs of the middle and lower terraces the Thames had quitted its course on the north side of the Purfleet Chalk and flowed in its present channel on the south side. No terrace gravel of the third stage occurs in the old channel. In Essex the London Clay can be traced in the tributary streams underneath the low terrace gravel at a level of about ten feet above ordnance datum. The surface gradually rises as it is traced northwards away from the river. Under the waterworks east of Walton the level is about the same. At Richmond it is rather less. Higher up the valley the low terrace rises with the river itself, though not to the same extent, and approaches the level of the middle terrace. The two are clearly separated from Isleworth through the village of Hampton as far as Hanworth Park, the London Clay forming a sharp feature all the way and cropping out at the surface here and there. But beyond Hanworth the boundary can only be traced at the surface by a slight inclination of the ground. The London Clay feature, however, seems to be continued underground, as it is found under the new reservoirs at Staines, four miles west of Hanworth. At the margin of the lower terrace the gravel often passes up the slopes in an attenuated bed which overlies and cuts into the brickearth resting on the middle terrace. In

* *Quart Journ. Geol. Soc.*, vol. xxxvi, p. 544.

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some places it exhibits the phenomenon described as "trail" by the Rev. O. Fisher. A section at West Bedfont, in Middlesex, showed two feet of gravel overlying about three feet of loam, under which were twelve feet of gravel with sandy beds. It is well seen in the sections at Grays, and has been described by Mr. Spurrell (*op. cit.*) at Crayford in Kent. In Middlesex this gravel appears to be of very general occurence, is of considerable thickness, and is found at all levels to the top of the highest terrace. It is often associated with much disturbance of the underlying beds, suggestive of ice pressure, and has even been correlated with the Boulder Clay by some observers. Though it is of much later date than that deposit, yet it seems to afford evidence of a climate of some severity following the temperate conditions under which the brickearth was formed. Much of this unstratified gravel may have been formed in the way suggested by Mr. C. Reid,* viz., by the wash of rains over a frozen soil. This view seems to be confirmed by the association of the unstratified gravel on the valley slopes with a stratified gravel at a lower level, which was most probably due to torrential floods of the river.

In this connection it may be observed that on the top of the Chalk at Grays there is a bed of flints and chalk fragments a few feet thick which shows signs of disturbance by pressure. Mr. H. B. Woodward, who examined the deposit, thought that while it bears some resemblance to the Coombe Rock of Sussex, which Mr. Reid regards as indicating a recurrence to arctic conditions after an interglacial episode, yet the bed might possibly be due to glaciation of the surface at the time when the Chalky Boulder-clay was formed. Its age at Grays is uncertain, but its position suggests that it is later than the denudation of the high terrace gravel. It is not improbable that it is contemporaneous with the low terrace gravel and with the Coombe Rock.

During the formation of the lower terrace the river flowed in a descending course nearly as far as the present limit of tides, but for the next thirty miles its level was the same; so that the sea level probably stood somewhat higher than at the present day. The coast section at Clacton seems to throw light on this point and may be mentioned here.† At the base of the cliff mammalian bones of the same species as those of the Thames brickearth were found in association with fresh-water shells. Higher up were beds containing marine and fresh-water shells, alternating with beds of peat, and at the top a ten foot bed of gravel. Hence there was an oscillation of sea level followed by the formation of gravel, which seems also to have been the case at Grays, the purely freshwater strata of that place being the equivalents of fluviomarine strata near the open sea.

The next and last deposits of the Thames valley are the alluvia of the marshes. It might be inferred from an examination of these deposits in Middlesex that they followed closely

* *Quart. Journ. Geol. Soc.*, vol. xlviii., p. 344.

† See W. H. Dalton, Geology of Colchester, *Mem. Geol. Survey*; and J. Brown, *Quart. Journ. Geol. Soc.*, vol. i., p. 341.

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on the formation of the low terrace gravel. Scarcely any denudation has taken place between them. But in reality the gravel is of much older date, and the interval is probably longer than that which separates any of the deposits hitherto described. Mr. Spurrell has shown* that a still later gravel, from ten to twenty feet thick, underlies the alluvium from Richmond to Tilbury. Its base is nearly at Ordnance datum at the former place, but it descends between 60 and 70 feet at the latter. Hence, after the deposition of the low terrace gravel, the Thames must have been an inland river 30 miles further east than at present, and the land must have been 60 or 70 feet higher at the least. How much more it is impossible to say. Eventually, however, the land began to subside and the alluvium with its intercalated beds of peat records the gradual encroachment of the sea to its present limit.

The alluvium in Middlesex is usually very thin. There is a broad expanse by the Colne and its associated streams, but it is often merely a peaty covering of the river gravel. At one spot, however, near Wraysbury, at the works of the Staines Reservoir, a narrow channel was found which had been cut through the gravel to the London clay underneath and filled up with alluvium. The alluvium yielded the skull of the Elk or Moose (*Alces machlis*), and remains of fallow deer, red deer, horse, and pig, which have been described by Mr. E. T. Newton.† The channel seems to have been an old course of the Wraysbury river from which it has been artificially diverted.

Teeth of Mammoth, tichorine Rhinoceros, and Horse were found in the low level gravel but probably they were not in place.

*Note.*—Besides the authors quoted above, reference has been made to the published work of Messrs. M. A. C. Hinton, A. S. Kennard, H. W. Monckton, T. Belt, J. G. Goodchild, J. Allen Brown, Prof. W. B. Dawkins and Prof. J. Geikie, where opinions have been put forward on some points similar to those here given.

## IX. Note on the Palæolithic Gravel of Savernake Forest, Wiltshire.‡

BY CLEMENT REID, F.R.S.

Knowle gravel-pit, from which so many Palæolitic implements have lately been obtained,§ lies on the east side of Savernake Forest, three miles N.N.E. of Savernake station, and just above the Marlborough and Hungerford Road. Its height is 450 feet above the sea; but only 40 feet above the bottom of the adjoining valley, which is a coombe in the porous Upper Chalk, dry at all times of the year, and apparently now never liable to floods. The water-level in the well at the cottage in the valley-bottom just below the pit is about forty feet below the

* *Proc. Geol Assoc.*, vol. xi., p. 89.

† *Quart. Journ. Geol. Soc.*, vol. lix., p. 80.

‡ Printed also in *Man* for April, 1903.

§ See Dr. Edgar Willett, on a collection of Palæolithic Implements from Savernake, *Journ. Anthrop. Inst.*, vol. xxxi., p. 310, 1901.

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surface, and is said only to vary slightly according to the season. Small lateral valleys run from south to north and have almost isolated the ridge on which Knowle Farm stands.

The palæolithic gravel, however, does not occupy the highest part of the ridge, which a mile south of the farm rises to 550 feet and is capped by the Eocene strata. This higher land spreads westward, and separates the dry coombe from the valley in which the Great Western Railway and the Canal now run. A still higher ridge (about 600 feet) separates the dry coombe from the Kennet valley on the north.

It seems clear, therefore, that the palæolithic gravel of Knowle is connected with the dry valley now occupied by the Marlborough and Hungerford road. The gravel lies fully 100 feet below the divides on the north and south, and is only 40 feet above the bottom of this valley; most of this forty feet seems, however, to have been excavated since the gravel was deposited.

The gravel does not occupy any well-defined terrace, and its character does not suggest ordinary river-action; it suggests rather intermittent floods washing angular material from the slopes above.

The deposit seen in Knowle pit consists of 12 or 15 feet of unstratified gravel of unworn or shattered flints, with 10 or 15% of Tertiary pebbles, rare greywethers, and numerous Palæolithic implements, which occur at all levels, though most abundantly towards the base. There are no seams of clean washed sand or gravel. The stones are embedded in a loamy ferruginous matrix, which has been so thoroughly decalcified by percolating water that it seems hopeless to expect fossils, unless some massive specimen, such as a tooth of an elephant, may have resisted decay. The removal of the Chalk-rubble which once evidently formed a considerable proportion of the gravel, helps to account for the entire obliteration of any bedding that may have existed. Even now the irregular solution of the solid chalk below is tending still more to mix the material, for the workmen recently broke into a small cave, caused by the subsidence of the lower part of the gravel into a pipe in the chalk, while the surface remained undisturbed.

The exact limits of the Palæolithic deposit are impossible to make out in so wooded a country and in the absence of sections. It apparently occupies irregular shallow channels in a shelf roughly parallel with the valley below, for at the same level as the Knowle pit, in a field nearly half a mile to the east, I picked up another Palæolithic implement.

The relation of this Palæolithic gravel to the erosion of the valleys seems to show that it is contemporaneous with the well-known deposits of Southampton Water, Bournemouth and the Avon Valley. There is nothing to suggest a more ancient date; but at the same time the gravel seems more ancient than the erosion of the lower part of the dry chalk-valley below, and

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more ancient than such deposits as the Coombe Rock of Brighton, or the lowest terrace gravels in the valleys of the south of England.

The reason for the occurrence of such large numbers of Palæolithic implements at certain points is not quite clear. I would suggest, however, that the sites of the camping grounds in a waterless and bare region of Chalk-downs would be determined by the occurrence of water-holes. In the case of the Knowle Farm locality the proximity of an outlier of clayey Tertiary strata probably gave the water, shelter, and firewood so essential to a race of hunters.

At present little is known as to the climatic conditions under which Palæolithic man existed in Britain; for though various slight indications suggest climatic extremes—with sharp alternations of cold drought and sudden floods—very few sedentary animals and plants have yet been collected in the same deposits. Pleistocene fossils have mostly been collected in other strata than those yielding the implements. To settle this question we need remains of plants or mollusca, for migrating mammals may leave a particular area for one half of the year only to return when a long period of drought or cold is over. This same enforced migration would compel Palæolithic man to follow the game, and would prevent permanent settlements except at favourable spots where water, shelter, and game could be found all the year round. In this connection it should not be forgotten that only as far away as Calais and Belgium the Palæolithic implements occur in true dust deposits, which graduate into the loess of the Rhine Valley, and suggest desert conditions approximating to those of Central Asia. In Britain the climate seems to have been milder; but still we have indications of drought in some of the mollusca and small mammals, and perhaps also in the extreme poverty of the flora.

## X. The Fossil Plants from the Canonbie Coal Field.

BY ROBERT KIDSTON, F.R.S.

The revision of the Scottish Coalfields furnished an opportunity for the re-examination of the Canonbie Coalfield during last season, with the view of obtaining a collection of plants for the purpose of zonal classification. When the Canonbie Coalfield was originally mapped by the Geological Survey in 1876–7, considerable stratigraphical difficulties were experienced in determining the sequence and correlation of the strata. Eventually the view was adopted that the coalfield belonged probably to the horizon of the Calciferous Sandstone Series of Scotland. After the ground was surveyed, Mr. Macconochie collected in 1879 a large suite of fossils from various horizons in that district including plants from the Canonbie Coalfield. The latter indicated that the beds containing them belonged to the true Coal Measures. When collecting in the Canonbie area Mr.



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Macconochie incidentally found plants in certain red shales near the border which suggested that the red shales and sandstones might be the representatives of the Upper Coal Measures of England.*

The examination of the plants collected during last season by Mr. Macconochie and myself, proves (1) that the Rowanburn coal seams belong to the Lower Coal Measures of England and Scotland, (2) that the coal seams formerly wrought in the Byre Burn represent the Middle Coal Measures, (3) that some at least of the red sandstones and shales lying between the Canonbie Coalfield and the Triassic rocks are on the horizon of the Upper Coal Measures.

### LOWER COAL MEASURES.

The coals at present worked at Rowanburn belong to this series. Mr. Kenneth Bowie showed us a few specimens from Blinkbonny and Engine Pit of the Canonbie Colliery, and additional specimens were collected by ourselves.

The following species have been observed:—

(*a*) Blinkbonny Pit, Rowanburn.

Roof of Main Coal.—

cf. *Sphenopteris* (*Renaultia*) *Schutzei* Stur. sp.
*Eremopteris artemisiaefolia*, Sternb. sp.
*Mariopteris muricata*, Schl. sp.
*Alethopteris lonchitica*, Schl. sp.
*Neuropteris heterophylla*, Brongt.
" *gigantea*, Sternb.
" *Blissi*. Lesqx.
*Calamites Cistii*, Brongt.
*Lepidodendron aculeatum*, Sternb.
*Cordaianthus Pitcairniae*, L. & H. sp.

From Blaes above nine Feet coal:—

*Calamites undulatus*. Sternb.

(*b*) Engine Pit, Rowanburn:—

From shales associated with five foot Coal.

cf. *Sphenopteris obtusiloba*, Brongt.
*Mariopteris muricata*, Schl. sp.
*Alethopteris lonchitica*, Schl. sp.
*Neuropteris heterophylla*, Brongt.
" *gigantea*, Sternb.
" *obliqua*, Brongt. sp.
" *Blissi*, Lesqx.
*Calamites*, sp.
*Lepidodendron obovatum*, Sternb.
*Lepidostrobus*, sp.
*Stigmaria ficoides*, Sternb. sp.
*Sphenophyllum cuneifolium*, Sternb. sp.

From floor of seven Foot seam.—

*Stigmaria ficoides*, Sternb. sp.

*The first public reference to the red shales and sandstones east of Canonbie, yielding plants resembling those of Upper Coal Measure age in England, was made in 1893 (Presidential address by R. Kidston, *Roy. Phys. Soc., Edinb.* 1893–4).

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The following table shows the vertical distribution of these species:—

| | U.C.M. | M.C.M. | L.C.M. |
|---|---|---|---|
| cf. *Sphenopteris obtusiloba*, Brongt. | | x | x |
| cf. *Sphen.* (*Renaultia*) *Schutzei*, Stur. sp. | | ? | x |
| *Eremopteris artemisiæfolia*, Sternb. sp. | | x | x |
| *Mariopteris muricata*, Schl. sp. | x | x | x |
| *Alethopteris lonchitica*, Schl. sp. | x | x | x |
| *Neuropteris heterophylla*, Brongt. | | x | x |
| „ *gigantea*, Sternb. | | x | x |
| „ *Blissi*, Lesqx. | | | x |
| „ *obliqua*, Brongt. | | x | x |
| *Calamites Cistii*, Brongt. | x | x | x |
| „ *undulatus*, Sternb. | x | x | x |
| *Lepidodendron aculeatum*, Sternb. | x | x | x |
| „ *obovatum*, Sternb. | | x | x |
| *Stigmaria ficoides*, Sternb. sp. | x | x | x |
| *Sphenophyllum cuneifolium*, Sternb. sp. | | x | x |
| *Cordaianthus Pitcairniæ*, L. & H. sp. | | x | x |

Of the sixteen species under consideration, all occur in the Lower Coal Measures; fourteen occur in the Middle Coal Measures, excluding one of whose occurrence in that horizon there is some doubt, and six are common to all the divisions of the Coal Measures. In all cases, the majority of Lower Coal Measure species occur in the Middle Coal Measures, but the Middle Coal Measures are distinguished from the Lower Coal Measures by the presence of species peculiar to that division, and these are entirely absent from the Canonbie Coals which contain a most typical Lower Coal Measure flora.

From the Upper Coal Measures the Rowanburn Coals are easily distinguished from the entire absence of characteristic Upper Coal Measure plants. There is, therefore, no doubt as to the Rowanburn Coals belonging to the Lower Coal Measures.

### MIDDLE COAL MEASURES.

The Middle Coal Measures appear in the Byre Burn a short distance above the Railway Viaduct near Gilnockie Station and extend as a narrow strip down each side of Byre Burn to its junction with the River Esk, where they cross the Esk and appear on both sides of the river for a short distance below Byreburnfoot. They are cut off to the north-west by a fault which throws them against the Carboniferous Limestone series a few yards above Byreburnfoot Bridge. On the Esk, a short distance below Byreburnfoot, the grey shales of the Middle Coal Measures gradually become stained red, and are succeeded by "Red Shales" and sandstones which are shown on both sides of the Esk till the newer Red Rocks (Trias) come in at Woodhouse, as shown in the published one-inch Sheet 11, a short distance below Canonbie Bridge. The horizon of the "Red Shales" will be referred to presently.

In the Middle Coal Measures several localities were found by Mr. Macconochie which yielded fossil plants, and one bed, passing across the mouth of Byre Burn a few yards above



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Byre Burn Bridge and which is again found on the Esk about 30 yards below the junction of Byre Burn with the river, was particularly rich in species of fossil plants.

A list of the species from the different localities in the Byre Burn Series, may now be given.

(*a*) Dark Shale bed in stream a few yards above Bridge at foot of Byre Burn, Canonbie. Horizon. Band lying between ¾ Coal and Main Coal.

*Sphenopteris mixta*, Schimper.
*Alethopteris lonchitica*, Schl. sp.
„ *Davreuxi*, Brongt. sp.
„ *Grandini*, Brongt. sp.
*Calamocladus equisetiformis*, Schl. sp.
*Calamostachys typica*, Schimper (*pars*).
*Sigillaria elegans*, Sternb. sp.
*Spenophyllum cuneifolium*, Sternb. sp.
„ „ *var. saxifragæfolium*, Sternb.
*Cordaites principalis*, Germar. sp.
*Cordaianthus cf. Pitcairniæ*, L. & H. sp.
*Cordaicarpus Cordai*, Geinitz. sp.

(*b*) Dark shale bed with ironstone band, River Esk, left bank, about 30 yards below junction of Byre Burn, and a short distance above Old Engine House. Horizon. Band lying between ¾ Coal and Main Coal.

*Sphenopteris Laurenti*, Andrae.
*Alethopteris Davreuxi*, Brongt. sp.
„ *Grandini*, Brongt. sp.
*Pecopteris*, sp.
*Calamites (Calamitina) undulatus*, Brongt. sp.
„ ( „ ) *Schutzei*, Stur.
„ ( „ ) *pauciramis*, Weiss.
„ ( „ ) sp.
„ *(Eucalamites) ramosus*, Artis.
„ *(Stylocalamites) Suckowii*, Brongt.
„ ( „ ) *Cistii*, Brongt.
*Calamocladus equisetiformis, Schl.* sp.
„ *charaeformis*, Sternb. sp.
*Calamostachys typica*, Schimper (*pars*).
cf. *Paracalamostachys Williamsoniana*, Weiss.
*Annularia radiata*, Brongt.
*Sigillaria elegans*, Sternb. sp.
*Pinakodendron Macconochiei*, n. sp. *
*Stigmaria ficoides*, Sternb. sp.
„ „ var.
*Sphenophyllum cuneifolium*, Sternb. sp.
*Cordaites principalis*, Germar sp.
*Cordaianthus Volkmanni*, Ett. sp.
*Cordaianthus*, sp.
*Carpolithes*, sp.
*Sternbergia*, sp.

(*c*) Byre Burn, about 300 yards above junction with River Esk. In soft grey shale.

*Neuropteris gigantea*, Sternb.

(*d*) River Esk, left bank, about 240 yards below junction of Byre Burn. In soft stained shale.

*Neuropteris gigantea*, Sternb.
*Lepidodendron, cf. lycopodioides*, Sternb.

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* See paper read before *Roy. Soc., Edinb.*

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(*e*) Byre Burn, underneath Railway Viaduct, near Gilnockie Station, Canonbie. In clayey sandy shale.

*Sphenopteris obtusiloba*, Brongt.
„ *multifida*, L. & H.
*Mariopteris muricata*, Schl. sp.
*Alethopteris lonchitica*, Schl. sp.

The specimens from this locality were collected by Mr Macconochie in 1879.

Localities (*a*) and (*b*) are different portions of the same band, which lies between the $\frac{3}{4}$ Coal and Main Coal of Byre Burn. The rarity of *Sigillaria* and absence of *Lepidodendron* in this zone is rather remarkable, as *Stigmaria* was very abundant.

Locality (*c*) holds a somewhat lower horizon in the series than localities (*a*) and (*b*); locality (*d*) is a little higher in the series than (*a*) and (*b*), while locality (*e*), the original locality from which plants were collected in Byre Burn, is the lowest horizon from which we have got plants from Byre Burn.

As all these localities are situated on the Byre Burn Coal Series, the species derived from them may be placed in one table, with the object of comparing the flora with that of the three divisions of the Coal Measures.

Fossil Plants from Byre Burn Coal Series.

| | U.C.M. | M.C.M. | L.C.M. |
|---|---|---|---|
| *Sphenopteris obtusiloba*, Brongt. | | x | x |
| „ *Laurenti*, Andrae. | | x | x |
| „ *mixta*, Schimper. | | x | |
| „ *multifida*, L. & H. | | x | |
| *Pecopteris*, sp. | | | |
| *Mariopteris muricata*, Schl. sp. | x | x | x |
| *Alethopteris lonchitica*, Schl. sp. | x | x | x |
| „ *Davreuxi*, Brongt. sp. | x | x | |
| „ *Grandini*, Brongt. sp. | x | | |
| *Neuropteris gigantea*, Sternb. | | x | x |
| *Calamites undulatus*, Sternb. | x | x | x |
| „ *Schützei*, Stur. | | x | x |
| „ *pauciramis*, Weiss. | | * | |
| „ *ramosus*, Artis. | x | x | x |
| „ *Suckowii*, Brongt. | x | x | x |
| „ *Cistii*, Brongt. | x | x | x |
| *Calamocladus equisetiformis*, Schl. sp. | x | x | x |
| „ *charaeformis*, Sternb. sp. | | x | |
| *Calamostachys typica*, Schimper (*pars*) | | x | x |
| *cf. Paracalamostachys Williamsoniana*, Weiss. | | | x |
| *Annularia radiata*, Brongt. | | x | x |
| *Lepidodendron*, cf. *lycopodioides*, Sternb. | | x | x |
| *Sigillaria elegans*, Sternb. sp. | | x | x |
| *Pinakodendron Macconochiei*, n. sp. | | * | |
| *Stigmaria ficoides*, Sternb. sp. | x | x | x |
| *Sphenophyllum cuneifolium*, Sternb. sp. | | x | x |
| „ „ var. *saxifragaefolium*, Sternb. | | x | x |
| *Cordaites principalis*, Germar. sp. | | x | x |
| *Cordianthus*, cf. *pitcairniæ*, L. & H. sp. | | x | x |
| „ *Volkmanni*, Ett. sp. | | x | |
| *Cordaicarpus Cordai*, Geinitz. sp. | | x | |
| *Carpolithus*, sp. | | | |
| *Sternbergia*, sp. | | | |

* These are the first British records for these fossils, but their horizon on the continent seems to agree with our Middle Coal Measures.

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Of the Byre Burn fossil plants a few extend into the Upper Coal Measures but these belong to those species which are common to all three divisions of the Coal Measures, with the exception of *Alethopteris Davreuxi*, Brongt. sp., which occurs only in the Upper and Middle Coal Measures. A greater number of the Byre Burn plants appear in the Lower Coal Measures, but after deducting these, there are several left which are peculiar to the Middle Coal Measures as far as we at present know. These are *Sphenopteris mixta*, Schimper, *Sphenopteris multifida*, L. and H., *Calamites pauciramis*; Weiss, *Calamocladus charæformis*, Sternb. sp., *Pinakodendron Macconochiei* n. sp., *Cordaianthus Volkmanni*, Ett. sp., and *Cordaicarpus Cordai*, Geinitz, sp. *Alethopteris Grandini*, Brongt. sp. which is tolerably plentiful at localities (*a*) and (*b*) has not previously been met with out of the Upper Coal Measures, and though *Sphenopteris Laurenti*, Andrae and *Sigillaria elegans*, Sternb. sp., also occur in the Lower Coal Measures, they are very rare on that horizon, being much more characteristic of the Middle Coal Measures.

From the evidence afforded by these fossils, I have no hesitation in classing the Byre Burn beds with the Middle Coal Measures of England.

### UPPER COAL MEASURES ("THE RED SHALES").

These occupy a considerable tract of ground and are well exposed in many places in the Parish of Canonbie and in the neighbouring part of Cumberland.

They are shown in the Rowanburn where they are faulted against the Lower Coal Measures at the Engine Pit. This fault runs almost east and west, and they are again seen faulted against the Carboniferous Limestone Series a very short distance below Blae Pot, on the Liddel Water, a little south of Penton Linns. From this line they extend southwards into Cumberland, meeting the newer Red Rocks (Trias) in the west, a short distance west of Riddings Junction.

Reference has already been made to their occurrence on the River Esk, where they succeed the Middle Coal Measures, a short distance below Byre Burnfoot, from which point they can be traced to Woodhouse, about a quarter of a mile below Canonbie Bridge.

The series, as a whole, is extremely barren of fossils, though it offers many good sections along the River Esk and the Liddel Water, and though these sections were more or less carefully examined by Mr. Macconochie and myself, they did not yield a single fossil plant.

At Jockie's Syke in Cumberland, 1 mile east by north of Riddings Junction, where, in 1879 Mr. Macconochie found a few small specimens, we were more successful, and discovered plant remains in three different bands.

The section exhibited here is, however, high up in the series and for this portion of it, the fossils indicate an Upper Coal Measure age.

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It is very unfortunate that the lower portion of the series along the River Esk is so barren (though plants may still be found in it, for the extent of ground to examine is considerable and our time was limited), for if the rocks form a continuous series with the Byre Burn Middle Coal Measures (though there may possibly be a fault between them), one would expect to find in the lower portion of the "Red Shales," a transition flora, composed partly of Middle and partly of Upper Coal plants, similar to the series which occurs above the Middle Coal Measures in the Potteries Coal Field, and which I have named the Upper Transition Series.* From the absence of any plant remains in the lower beds of the red shales on the Esk, I am unable to determine whether they belong to this Upper Transition Series or to the Upper Coal Measures.

The flora of the upper beds, however, as developed in Jockie's Syke, have a distinct Upper Coal Measure facies, and though one misses from the list of plants collected such typical names as *Pecopteris arborescens* and its allies, several of the *Cyatheites Pecopterids* occur, but the preservation of the specimens was so unsatisfactory, that it was impossible to determine them specifically. In outline, one agrees perfectly with *Pec. arborescens*, Schloth sp., but in absence of the nervation, a satisfactory determination of the *Cyatheites Pecopterids* cannot be made. In most of the other ferns the nervation was well seen.

Of course it is difficult sometimes to draw the exact line between the Upper Transition Series and the Upper Coal Measures, for they are only the upper and lower end of a continuous chain, but taking all the available evidence into consideration, I think we must class the "Red Shales" of Jockie's Syke with the Upper Coal Measures.

The following species were collected from the "Red Shales" at Jockie's Syke, 1 mile east by north of Riddings Junction, Cumberland :—

Locality (a) Streamlet entering on right of main stream, 30 yards south of North British Railway. In soft red and greenish shales.

*Pecopteris* (Cyatheites).
(Two species at least).
*Alethopteris Serlii*, Brongt. sp.
„ *Grandini*, Brongt. sp.
„ *aquilina*, Schl. sp.
*Neuropteris ovata*, Hoffm.
„ *flexuosa*, Sternb.
„ *Scheuchzeri*, Hoffm.
*Calamites undulatus*, Sternb.
*Calamitina*, sp.
*Calamocladus equisetiformis*, Schl. sp.
*Annularia radiata*, Brongt.
*Annularia stellata*, Schl. sp.
*Lepidodendron fusiforme*, Corda, sp.
*Lepidophyllum*, sp.

* Kidston, "On the various divisions of British Carboniferous Rocks as determined by their Fossil Flora," *Proc. Roy. Phys. Soc. Edin.*, vol. xii., p. 228–229, 1894 ; also "Additional Records and Notes on the Fossil Flora of the Potteries Coal Field, North Staffordshire," *Trans. North Staffordshire Field Club*, 1897. Stoke on Trent.

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Locality (b) Main Stream (Jockie's Syke) about 125 yards above Railway. In purplish shale.

*Alethopteris aquilina*, Schl. sp.
„ *Serlii*, Brongt. sp.
*Neuropteris flexuosa*, Sternb.
*Stigmaria ficoides*, Sternb. sp.

Locality (c) main stream of Syke, about 300 yards above the railway. In purplish clayey shales.

*Pecopteris* (*Cyatheites*).
*Alethopteris*, sp.
*Neuropteris flexuosa*, Sternb.
„ *Scheuchzeri*, Hoffm.

The vertical distribution of these fossils is seen in the following table.

| | U.C.M. | M.C.M. | L.C.M. |
|---|---|---|---|
| *Pecopteris* (*Cyatheites*), species | x | | |
| *Alethopteris aquilina*, Schl. sp. | x | x | |
| „ *Grandini*, Brongt. sp. | x | x | |
| „ *Serlii*, Brongt. sp. | x | | |
| *Neuropteris ovata*, Hoffm. | x | | |
| „ *flexuosa*, Sternb. | x | | |
| „ *Scheuchzeri*, Hoffm. | x | x | |
| *Calamites undulatus*, Sternb. | x | x | x |
| *Calamitina*, sp. | | | |
| *Calamocladus equisetiformis*, Schl. sp. | x | x | x |
| *Annularia radiata*, Brongt. | x | x | x |
| „ *stellata*, Schl. sp. | x | | |
| *Lepidodendron fusiforme*, Corda sp. | | | x |
| *Lepidophyllum*, sp. | | | |
| *Stigmaria ficoides*, Sternb. sp. | x | x | x |

An analysis of the fossil plants found at Jockie's Syke shows that of the 13 names available for comparison, 12 occur in the Upper Coal Measures, and of these 5 are peculiar to that horizon, 7 are common to Upper and Middle Coal Measures, and 5 also occur in the Lower Coal Measures, but of these 5, 4 are common to all the divisions of the Coal Measures, while the 5th, *Lepidodendron fusiforme*, Corda sp. I have only seen previously in the Lower Coal Measures.

This analysis shows that at least the upper portion of the "Red Shales" must be classed with the Upper Coal Measures, for owing to the entire absence of a single characteristic Middle Coal Measure Species, it seems impossible to regard these beds as belonging to the Upper Transition Series.

The fact of *Lepidodendron fusiforme*, Corda sp. occurring in the Upper Coal Measures, which has hitherto only been discovered in the Lower Coal Measures (where, however, it is extremely rare), does not vitiate the conclusion arrived at in regard to the age of these "Red Shales," but merely shows that *Lepidodendron fusiforme* is one of those species which extends throughout the whole of the Coal Measures. It is also the only plant discovered at Jockie's Syke, which had not previously been found in the Upper Coal Measures of other areas.

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# APPENDIX XI.

## CATALOGUE of TYPES and FIGURED SPECIMENS of BRITISH GASTEROPODA and SCAPHOPODA from the RHÆTIC BEDS, LIAS, and INFERIOR OOLITE, preserved in the MUSEUM of PRACTICAL GEOLOGY, London.

BY H. A. ALLEN, F.G.S.

Each specimen is entered under the name given to it when first figured or described. When the author's name is placed in parentheses, (Phillips), it refers only to the species and not to the genus. The letter **T** indicates that the specimen is the type of the species. The identity of some few specimens is not quite certain: these are marked [**Doubtful**]. The figures in brackets, [7009], correspond to the number in the Museum Register.

The following abbreviations are employed :—

Ann. Mag. Nat. Hist.: Annals and Magazine of Natural History, London.

"Cotteswold Hills": "The Cotteswold Hills Hand-book," by J. Lycett, London.

Geol. Mag.: The Geological Magazine, London.

M. G. S.: Memoirs of the Geological Survey of the United Kingdom.

Mon. Pal. Soc.: Monographs of the Palæontographical Society, London. (The dates quoted refer to year of *issue* only).

Proc. Cotteswold Nat.: Proceedings of the Cotteswold Naturalists' Club, London.

Q. J. G. S.: Quarterly Journal of the Geological Society of London.

Rep. Belfast Nat. App. 1: Seventh Annual Report of the Belfast Naturalists' Field Club, Appendix 1, Belfast.

"Yorkshire Lias": "The Yorkshire Lias," by R. Tate & J. F. Blake, London.

### RHÆTIC.

**Natica pylensis**, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1865, pl. iv., f. 10, p. 89.
Rhætic (*Avic. contorta* zone). [7827] Pyle, Glamorganshire.

### LIAS.

**Actæonina chrysalis**, Tate. **T**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 23, p. 356.
Middle Lias (*A. spinatus* zone). [8463] Eston.

**Actæonina ilminsterensis**, Moore.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 7, p. 355.
Middle Lias. [8462] Cleveland.

**Cerithium acriculum**, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 1, p. 351.
Middle Lias (*A. spinatus* zone). [7967] Hawsker.



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**Cerithium Dayii**, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 7.
Middle Lias. [7966] Down Cliff, Charmouth

**Cerithium ibex**, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 8, p. 405.
Lower Lias (*A. Jamesoni* zone). [7960] Cheltenham.

**Cerithium liassicum**, Moore.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 18, p. 351.
Middle Lias (*A. spinatus* zone). [7968] Eston.

**Cerithium ligaturalis**, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 7.
Lower Lias. [7961] Redmile, Lincolnshire.

**Cerithium Slatteri**, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 7, p. 406.
Lower Lias (*A. Jamesoni* zone). [7963] Cheltenham.

**Cerithium subfistulosa**, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Lower Lias. [7964] Redmile, Lincolnshire.

**Cerithium tenuicostatum** (Portlock).
R. Tate, Rep. Belfast, Nat., Appendix 1, 1870, pl. 1, f. 8, p. 15.
Lower Lias. [7965] Ballintoy.

**Chemnitzia acula**, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 10, p. 354.
Upper Lias (*A. annulatus* zone). [7988] Glaizedale.

**Chemnitzia citharella**, Tate. **T.**
R. Tate. "Yorkshire Lias," 1876, pl. x., f. 4, p. 354.
Middle Lias (*A. margaritatus* zone). [7991] Staithes.

**Chemnitzia complicata**, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Middle Lias (Marlstone). [7992] Hyde near Yeovil.

**Chemnitzia nuda** (Muenster).
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 9, p. 354.
Middle Lias (*A. margaritatus* zone). [7993] Huntcliff.

**Chemnitzia punctata**, Tate. **T.**
R. Tate, Rep. Belfast, Nat., App. 1, 1870, pl. i., f. 11, p. 15.
Lower Lias (*A. angulatus* zone). [7989] Island Magee.

**Chemnitzia semitecta**, Tate.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 23, p. 353.
Middle Lias (*A. margaritatus* zone). [8461] Staithes.

**Chemnitzia trivia**, Tate. **T.**
R. Tate, Geol. Mag., vol. viii, 1871, p. 8.
Lower Lias. [7990] Bridgend.

**Cryptænia Brycei**, Tate.
R. Tate, Rep. Belfast Nat., App. I., 1870, pl. i, f. 13, p. 16.
Lower Lias (*A. angulatus* zone). [7936] Garron Point, Antrim.

**Dentalium elongatum**, Muenster.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 28, p. 332.
Middle Lias (*A. spinatus* zone). [7997] Kettleness.

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**Dentalium etalense**, Terquem and Piette.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 13, p. 332.
Lower Lias (*A. angulatus* zone). [7998] Redcar.

**Dentalium giganteum**, Phillips.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 10, p. 331.
Lower Lias. [8000] Hawsker Cliff.

**Dentalium limatulum**, Tate.
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 18, p. 332.
Lower Lias. [8001] Redcar.

**Dentalium Portlocki**, Tate. **T.**
R. Tate, Rep. Belfast Nat., App. 1., 1870, pl. i., f. 15, p. 17.
Lower Lias (*A. angulatus* zone). [7999] Island Magee.

**Discohelix aratus**, Tate.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 5, 5*a*, p. 340. (See also *Straparolus*.)
Middle Lias (*A. margaritatus* zone). [7977] Staithes.

**Discohelix Oppeli** (Martin).
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 8*a*, *b*, p. 340.
Lower Lias (*A. Bucklandi* zone). [7982] Redcar.

**Discohelix semiclausus**, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 14, p. 341.
Lower Lias (*A. angulatus* zone). [7980] Redcar.

**Discohelix striatus** (Piette).
R. Tate, "Yorkshire Lias," 1876, pl. ix., figs. 8, 9, p. 340.
Lower Lias (*A. Bucklandi* zone) [7983] Redcar.

**Eucyclus acuminatus** (Chapuis and Dewalque).
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 20, p. 346.
Lower Lias (*A. angulatus* zone). [7957] Redcar.

**Eucyclus cingendus**, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl., x., f. 15, p. 348.
Middle Lias. [7958] Eston.

**Eucyclus conspersus**, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 11*a*, *b*, p. 347.
Middle Lias. [7959] Eston.

**Eucyclus selectus** (Chapuis and Dewalque).
R. Tate, "Yorkshire Lias," 1876, p. 346.
Lower Lias (*A. Bucklandi* zone). [8473] Marske Bay.

**Eucyclus undulatus** (Phillips).
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 12*a*, *b*, p. 347.
Middle Lias (*A. spinatus* zone). [8466] Upleatham.

**Euomphalus minutus**, Schuebler.
R. Tate, "Yorkshire Lias," 1876, p. 341. (See also *Natica pilula*).
Upper Lias. [8474] Scagdale.

**Exelissa numismalis**, Tate. **T.**
R. Tate, Ann. Mag. Nat. Hist., vol. iv., 1869, p. 417; Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 5, p. 403.
Lower Lias (*A. Jamesoni* zone). [7976] Cheltenham.

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**Hydrobia solidula** (Dunker).
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 6, p. 345.
Lower Lias (*A. oxynotus* zone). [7983] Robin Hood's Bay.

**Littorina biornata**, Tate. **T.**
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 17, p. 404.
Lower Lias (*A. Jamesoni* zone). [7984] Charmouth.

**Littorina clevelandica**, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 17*a*, *b*, p. 348.
Middle Lias (*A. margaritatus* zone). [7985] Huntcliff.

**Monodonta modesta**, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Middle Lias (Marlstone). [8007] Churchdown, Cheltenham.

**Natica pilula**, Tate. **T.**
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Upper Lias. (See also *Euomphalus minutus*). [7912] Dumbleton.

**Natica purpuroidea**, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 13, p. 349.
Lower Lias. [7996] Redcar.

**Nerita alternans**, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x, f. 16*a*-*c*, p. 333.
Middle Lias (*A. spinatus* zone). [8465] Upleatham.

**Patella gratans**, Tate. **T.**
R. Tate, Geol. Mag., vol. ii., 1875, p. 204.
Middle Lias (*A. spinatus* zone). [7969] Uley, Gloucestershire.

**Patella suttonensis**, Tawney. **T.**
E. B. Tawney, Q. J. G. S., vol. xxii., 1866, pl. iv., f. 9, 9*a*, p. 88.
Lower Lias. [7945] Sutton.

**Pitonillus sordidus**, Tate. **T.**
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 19*a*-*c*, p. 343.
Lower Lias (*A. Bucklandi* zone). [7986] Redcar.

**Pleurotomaria concava**, Martin.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 27, p. 339
Lower Lias (*A. Bucklandi* zone). [7932] Redcar.

**Pleurotomaria helicinoides** (Roemer).
R. Tate, "Yorkshire Lias," 1876, pl. x, f. 7*a*, *b*, p. 338.
Middle Lias (*A. spinatus* zone). [8464] Eston.

**Pleurotomaria Hennocqui** ? Terquem.
R. Tate, "Yorkshire Lias," 1876, p. 337.
Lower Lias. [8470] Marske Bay.

**Pleurotomaria similis**, J. Sowerby.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 4, p. 337.
Lower Lias (*A. Bucklandi* zone). [7931] Redcar.

**Pleurotomaria tectaria**, Tate. **T.**
R. Tate, Rep. Belfast Nat., App. I., 1870, p. 17.
Lower Lias (*A. angulatus* zone). [7933] Between Garron Point and Red Bay

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**Pleurotomaria tectaria**, Tate.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 26, p. 338.
Lower Lias. [7934] Redcar.

**Rissoa nana** (Martin).
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 17, p. 345.
Lower Lias (*A. Bucklandi* zone). [8468] Redcar.

**Solarium inornatum**, Tate. T.
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Middle Lias. [7987] Chipping Campden.

**Solarium lucens**, Tate. T.
R. Tate, Geol. Mag., vol. viii, 1871, p. 8.
Lower Lias (*A. Henleyi* zone). [7956] Mickleton.

**Solarium Thomsoni**, Tate. T.
R. Tate, Rep. Belfast Nat., App. I, 1870, pl. i., f. 9, p. 16.
Lower Lias (*A. angulatus* zone). [7954] Glenarm.

**Straparolus aratus**, Tate. T.
R. Tate, Q. J. G. S., vol. xxvi., 1870. pl. xxvi., f. 21, p. 404. (See also *Discohelix*).
Lower Lias (*A. Jamesoni* zone). [7978] Charmouth.

**Straparolus bellulus**, Tate. T.
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 22, p. 404.
Lower Lias (*A. Jamesoni* zone). [7979] Charmouth.

**Straparolus wrightianus**, Tate. T.
R. Tate. Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 23, p. 404.
Lower Lias (*A. Jamesoni* zone). [7981] Charmouth.

**Tornatella capricorni**, Tate. T.
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 18, p. 405.
Lower Lias (*A. Jamesoni* zone). [7935]
Aston Magna, Gloucestershire.

**Trochus inconstans**, Tate. T
R. Tate, Geol. Mag., vol. viii., 1871, p. 8.
Lower Lias. [7946] Bridgend, Glamorgan.

**Trochus redcarensis**, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 14*a–c*, p. 342.
Lower Lias (*A. Bucklandi* zone). [7947] Redcar.

**Trochus Robigus**, Tate. T
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 3*a*, *b*, p. 341.
Lower Lias (*A. oxynotus* zone). [7948] Robin Hood's Bay.

**Trochus solitarius**, Tate. T.
R. Tate, Q. J. G. S., vol. xxxi., 1875, p. 506, f. 2 (Text figure).
Lower Lias [7949] Munger.

**Trochus Thetis**, Muenster.
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 4, p. 403; "Yorkshire Lias," 1876, p. 342.
Lower Lias (*A. Jamesoni* zone). [7950] Aston Magna.

**Turbo aciculus** (Stoliczka).
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 22, p. 344.
Middle Lias (*A. spinatus* zone). [8002] Cleveland.

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**Turbo admirandus**, Tate. T.
R. Tate, Q. J. G. S., vol. xxvi., 1870, pl. xxvi., f. 10, p. 403.
Lower Lias (*A. Jamesoni* zone). [7951] Cheltenham.

**Turbo cyclostoma**, Benz.
R. Tate "Yorkshire Lias," 1876, pl. ix., f. 19, p. 344.
Middle Lias. [8003] Hawsker.

**Turbo latilabrus** (Stoliczka).
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 15, p. 343.
Middle Lias (*A. spinatus* zone.) [8004] Eston.

**Turbo lineatus**, Moore.
R. Tate "Yorkshire Lias," 1876, pl. ix., f. 20, p. 343.
Middle Lias (Ironstone). [8005] Upleatham.

**Turbo Philemon**, d'Orbigny.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 25, p. 344.
Lower Lias. [7952] Redcar.

**Turbo reticulatus**, Moore.
R Tate, "Yorkshire Lias," 1876, p. 344.
Lower Lias (*A. Bucklandi* zone). [8471] Redcar.

**Turbo solarium**, Piette.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 16, p. 343.
Lower Lias (*A. Bucklandi* zone). [7953] Redcar.

**Turbo Wilsoni**, Tate. T.
R. Tate, "Yorkshire Lias," 1876, pl. x., f. 5*a*, *b*, p. 344.
Lower Lias (*A. Bucklandi* zone). [7955] Redcar.

**Turritella Deshayesea**, Terquem.
R. Tate, "Yorkshire Lias," 1876, p. 349.
Lower Lias (*A. Bucklandi* zone). [8467] Redcar.

**Turritella Dunkeri**, Terquem.
R. Tate, "Yorkshire Lias," 1876, pl. ix., f. 3, p. 350.
Lower Lias (*A. oxynotus* zone). [8472] Robin Hood's Bay.

**Turritella regularis** (Terquem and Piette).
R. Tate, "Yorkshire Lias," 1876, p. 350.
Lower Lias (*A. oxynotus* zone). [8006] Robin Hood's Bay.

## INFERIOR OOLITE.

**Acteonina antiqua**, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. iv., f. 9, p. 125.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 6, p. 477.
Inferior Oolite. [8015] Rodborough Hill.

**Acteonina convoluta**, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. iv., f. 8, p. 125. Re-figured as **Actæonina? convoluta**: W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 7, p. 477.
Inferior Oolite. [8016] Rodborough Hill.

**Actæonina gigantea** (Deslongchamps) T.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 2, p. 475.
Inferior Oolite. [8017] Cotteswold Hills.

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**Acteonina ovata**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79.
W. H. Hudleston, Mon. Pal. Soc., 1896, p. 475.
Inferior Oolite. [8113] Nailsworth?

**Alaria solida** *vide* **Rostellaria.**

**Alaria unicornis** *vide* **Rostellaria.**

**Amberleya biserta** (Phillips).
W. H. Hudleston, Geol. Mag., 1884, pl. viii., f. 11*a–c*, p. 249; Mon. Pal. Soc., 1892, pl. xxiii., f. 2, p. 288.
Inferior Oolite (Dogger). [8039] Blue Wyke, Yorkshire.

**Bulla Favrei**, Lycett. T.
J. Lycett, "Cotteswold Hills," 1857, pl. iv., f. 7, p. 125.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 10, p. 481.
Inferior Oolite. [8014] Avening, Minchinhampton.

**Ceritella sculpta**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80.
Inferior Oolite. [5364] Leckhampton.

**Ceritella tumidula**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i, 1853, p. 80.
Inferior Oolite. [5365] Leckhampton.

**Cerithinella Brodiei**, Hudleston. T.
W. H. Hudleston, Mon. Pal. Soc., 1889, pl. xii., f. 4*a*, *b*, p. 187.
Inferior Oolite. [8044] Nailsworth.

**Cerithium "cingula,"** Hudleston.
W. H. Hudleston, Mon Pal. Soc., 1889, pl. ix., f. 8, p. 162.
Inferior Oolite. [8045] Nailsworth.

**Cerithium leckhamptonense**, Hudleston. T.
W. H. Hudleston, Mon. Pal. Soc., 1889, pl. ix., f. 2, p. 157.
Inferior Oolite. [8047] Leckhampton Hill.

**Cerithium (Colina) Lycetti**, Hudleston. T.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 22*a*, *b*, p. 485.
Inferior Oolite. [8049] Nailsworth.

**Cerithium turris**, Hudleston. T.
W. H. Hudleston, Geol. Mag., 1884, pl. iii., f. 13, 13*a*, p. 61; Mon. Pal. Soc. 1889, pl. ix., f. 15, p. 166.
Inferior Oolite (Dogger). [8048] Blue Wyke

**Cerithium sp.** near to *C. variculosum*, Deslongchamps.
W. H. Hudleston, Mon. Pal. Soc., 1889, pl. x., f. 1, p. 166.
Inferior Oolite. [8046] Rodborough Hill.

**Chemnitzia elegans**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79.
Inferior Oolite. [5363] Leckhampton.

**Chemnitzia gracilis**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, pl. xi., f. 3, p. 418; Proc. Cotteswold Nat., vol. i., 1853, pl. ii., f. 3, p. 79. Re-figured as **Nerinæa gracilis**: "Cotteswold Hills," 1857, pl. ii., f. 3, 3*a*, p. 124; and W. H. Hudleston, Mon. Pal. Soc., 1890, pl. xii., f. 13*a*, *b*, p. 196.
Inferior Oolite. [8082, 8083] Nailsworth.

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**Chemnitzia procera**, Deslongchamps.
J. Lycett, "Cotteswold Hills," 1857, pl. ii., f. 1, p. 150.
Inferior Oolite. [8090] Nailsworth.

**Cirrus Etheridgii**, *vide* **Turbo.**

**Cryptaulax scobina** (Deslongchamps) *var.*
W. H. Hudleston, Mon. Pal. Soc., 1889, pl. xi., f. 11, p. 181.
Inferior Oolite Sands. [7994] Nailsworth.

**Cylindrites attenuatus**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79.
Inferior Oolite. [5361] Leckhampton.

**Cylindrites cylindricus**, Morris and Lycett, *var.*
W. H. Hudleston, Mon. Pal. Soc., 1896. pl. xliii., f. 16*a*, *b*, p. 481.
Inferior Oolite. [8018] Nailsworth ?

**Cylindrites mamillaris**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79.
Inferior Oolite. [5362] Leckhampton.

**Cylindrites tabulatus**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 418; Proc. Cotteswold Nat., vol. i., 1853, p. 79. Figured W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 14 *a*, *b*, p. 479.
Inferior Oolite. [8112] Nailsworth.

**Cylindrites tabulatus**, Lycett, *var* **weldonis**, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xliii., f. 13 *a*, *b*, p. 479.
Inferior Oolite. [8019] Weldon.

**Delphinula quaterno-cingillata**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 416; Proc. Cotteswold Nat., vol. i., 1853, p. 77.
Inferior Oolite. [8108] Nailsworth.

**Delphinula (Turbo) santonis**, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1894, pl. xxx., f. 18, 18 *a*, p. 369.
Inferior Oolite. [8037] Santon, Lincolnshire.

**Emarginula alta**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 416; Proc. Cotteswold Nat., vol. i., 1853, p. 77. Figured as **Rimula alta**: W. H. Hudleston, Mon. Pal. Soc., 1894, pl. xli., f. 18 *a*, *b*, p. 455.
Inferior Oolite. [8024] Locality doubtful.

**Emarginula granulata**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 415; Proc. Cotteswold Nat., vol. i., 1853, p. 76.
Inferior Oolite. [5329] Leckhampton.

**Emarginula leckhamptonensis**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 415; Proc. Cotteswold Nat., vol. i., 1853, p. 76.
Inferior Oolite. [5333] Leckhampton.

**Eulima parvula**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1853, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80.
Inferior Oolite. [5371] Leckhampton.

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**Fissurella Brodiei**, Lycett [**Doubtful**]. **T.**
J Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 415 ; Proc. Cotteswold Nat., vol. i., 1853, p. 76.
Inferior Oolite. [5335] Leckhampton.

**Fusus ? carino-crenatus**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 420 ; Proc. Cotteswold Nat., vol. i., 1853, p. 81. Figured as **Purpurina (Eucycloidea) carino-crenata**: W. H. Hudleston, Mon. Pal. Soc., 1888, pl. ii., f. 7 *a*, *b* p. 97.
Inferior Oolite. [8040] Locality doubtful.

**Hamusina oppelensis**, *vide* **Turbo.**

**Malaptera Bentleyi**, (Morris and Lycett).
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. iii., f. 1*a*, p. 101.
Inferior Oolite (Collyweston Slate). [8102] Collyweston.

**Natica adducta**, Phillips, *var.* **globata**, Hudleston.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 6, p. 259.
Inferior Oolite (Lower Trigonia-Grit). [8093] Cheltenham.

**Natica adducta** *var* **oppelensis**, *vide* **Natica oppelensis.**

**Natica canaliculata**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417 ; Proc. Cotteswold Nat., vol. i., 1853, p. 78. Figured "Cotteswold Hills," 1857, pl. iii., f. 10, p. 155.
Inferior Oolite. [8092] Nailsworth.

**Natica cincta ?** Phillips.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 17, p. 259.
Inferior Oolite [8099] Cheltenham.

**Natica hulliana**, Lycett. **T.**
Morris & Lycett, Mon. Pal. Soc. Suppl., 1863, pl. xli., f. 2, p. 13.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 12, p. 262.
Inferior Oolite. [8042] Nailsworth.

**Natica cf. Michelini**, d'Archaic.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 18*a*, *b*, p. 269.
Inferior Oolite. [8091] Nailsworth.

**Natica oppelensis**, Lycett. **T.**
J. Lycett, "Cotteswold Hills," 1857, pl. i., f. 4, p. 123. Refigured as **Natica adducta**, *var* **oppelensis**: W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xx., f. 2, p. 258.
Inferior Oolite Sands. [8098] Nailsworth.

**Nerinæa cotteswoldiæ**, Lycett. **T.**
J. Lycett "Cotteswold Hills," 1857, pl. ii., f. 2 *a*, *b*, p. 124.
Inferior Oolite. [8085] Nailsworth.

**Nerinæa gracilis**, *vide* **Chemnitzia.**

**Nerinæa Jonesii**, Lycett. **T.**
J. Lycett, "Cotteswold Hills," 1857, pl. ii., f. 4, p. 124. Refigured W. H. Hudleston, Mon. Pal. Soc., 1890, pl. xv., f. 9 *a*, *b*, p. 218.
Inferior Oolite. [8089] Nailsworth.

**Nerinæa oppelensis**, Lycett. **T.**
J. Lycett, "Cotteswold Hills," 1857, pl. ii., f. 6 *a*, *b*, p. 123.
Inferior Oolite. [8086] Selsley Hill.



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**Nerinæa pseudocylindrica**, d'Orbigny.
J. Lycett, "Cotteswold Hills," 1857, pl. ii., f. 5, p. 166.
Inferior Oolite. [8088] Nailsworth.

**Nerinæa santonis**, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1890, pl. xvi., f. 8 *b*, *c*, p. 224.
Inferior Oolite. [8087] Santon.

**Nerinæa subcingenda**, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1890, pl. xiv., f. 16 *a*, p. 212.
Inferior Oolite. [8084] Santon.

**Nerita cassidiformis**, Lycett. **T.**
J. Lycett, Ann. Mag. Nat. Hist. vol. vi., 1850, p. 416; Proc. Cotteswold Nat. vol. i, 1853, p. 77.
Inferior Oolite. [5342] Leckhampton.

**Nerita minuta**, Sowerby, *var.* **tumidula**, Phillips.
W. H. Hudleston, Geol. Mag., vol. i., 1884, pl. ix., f. 4 *a*, *b*, p. 296.
Inferior Oolite (Dogger). [8022] Blue Wyke, Scarborough.

**Neritopsis (?Turbo) lævigata** (Phillips) *var.* **A.**
W. H. Hudleston, Geol. Mag., vol. ii., 1885, pl. ii., f. 2, p. 49. Refigured as "**Neritopsis lævigata.**" W. H. Hudleston, Mon. Pal. Soc., 1894, pl. xxviii., f. 10, p. 344.
Inferior Oolite (Dogger). [8023] Blue Wyke, Scarborough.

**Patella** cf. **cingulata**, Muenster.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xlii., f. 5 *a–c*, p. 461.
Inferior Oolite. [8420] Rollwright, Oxfordshire.

**Patella nitida**, Deslongchamps.
W. H. Hudleston, Mon. Pal. Soc., 1896, pl. xlii, f. 7 *a*, *b*, p. 461.
Inferior Oolite. [8029] Leckhampton?

**Patella retifera**, Lycett **[Doubtful] T.**
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 415; Proc. Cotteswold Nat., vol. i., 1853, p. 76.
Inferior Oolite. [5327] Leckhampton.

"**Phasianella**" **elegans** (Morris and Lycett).
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xix., f. 11 *a*, p. 252.
Inferior Oolite (Lincolnshire Limestone). [4393] Locality doubtful.

**Pleurotomaria Aglaia**, d'Orb. *var.*
J. Morris in E. Hull, M.G.S., Cheltenham, 1857, pl. i., f. 7,7 *a-d*, p. 104.
Inferior Oolite (Pea-grit). [8020, 8021] Crickley Hill, Cheltenham.

**Purpurina aperta**, *vide* **Turbo elaboratus.**

**Purpurina aspera**, Hudleston. **T.**
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. i., f. 11 *e*, p. 91.
Inferior Oolite. [8094] Bradford Abbas.

**Purpurina carino-crenata**, *vide* **Fusus ?**

**Purpurina inflata**, Tawney.
W. H. Hudleston, Mon. Pal. Soc., 1888, pl., ii., f. 2 *f*, p. 92.
Inferior Oolite [8096] Rodborough Hill.

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**Purpurina rotunda**, Hudleston.
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. ii., f. 3 *d*, p. 93.
Inferior Oolite. [8095] Bradford Abbas.

**Purpurina sp.**, *vide* **Turbo elaboratus.**

**Rimula alta**, *vide* **Emarginula.**

**Rissoina obtusa**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi, 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80.
Inferior Oolite. [5373] Leckhampton.

**Rostellaria solida**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80. Figured as **Alaria solida**: W. H. Hudleston, Mon. Pal. Soc., 1889, pl. vii., f. 5, p. 139.
Inferior Oolite. [8080] Nailsworth.

**Rostellaria spinigera**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80. Figured W. H. Hudleston, Mon. Pal. Soc., 1889, pl. vii., f. 4, p. 138.
Inferior Oolite. [8079] Nailsworth.

**Rostellaria unicornis**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80. Figured as **Alaria unicornis**: W. H. Hudleston, Mon. Pal. Soc., 1888, pl. v., f. 1, p. 119.
Inferior Oolite. [8081] Nailsworth.

**Scalaria pygmæa**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 419; Proc. Cotteswold Nat., vol. i., 1853, p. 80.
Inferior Oolite. [5366] Leckhampton.

**Spinigera didactyla**, Hudleston, *var.*
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. iii., f. 6*d*. p. 106.
Inferior Oolite. [8101] Bradford Abbas?

**Spinigera recurva**, Hudleston. T.
W. H. Hudleston, Mon. Pal. Soc., 1888, pl. iii., f. 5*f*, p. 105.
Inferior Oolite. [8100] Bridport.

**Straparollus "tuberculosus-dexter,"** Hudleston.
W. H. Hudleston, Mon. Pal. Soc., 1892, pl. xxvi., f. 1, p. 317.
Inferior Oolite. [8036] Dundry

**Trochotoma calix** (Phillips).
J. Lycett, "Cotteswold Hills" 1857, pl. iii., f. 6, p. 166.
Inferior Oolite. [8028] Cotteswold Hills.

**Trochotoma carinata**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417; Proc. Cotteswold Nat., vol. i., 1853, p. 78; Figured "Cotteswold Hills" 1857, pl. iv., f. 5, p. 167.
Inferior Oolite. [8027] Rodborough.

**Trochotoma depressiuscula**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417; Proc. Cotteswold Nat., vol. i., 1853, p. 78.
Inferior Oolite. [8114] Rodborough.



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**Trochus alternans**, Lycett. T
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417 ; Proc. Cotteswold Nat., vol. i., 1853, p. 78.
Inferior Oolite. [5354] Leckhampton.

**Trochus bi-cingendus**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 416 ; Proc. Cotteswold Nat., vol. i., 1853, p. 77. Figured as **Trochus ? bicingendus**: W. H. Hudleston, Mon. Pal. Soc., 1894, pl. xxxi., f. 15, p. 389.
Inferior Oolite. [8041] Nailsworth.

**Trochus cingillato-serratus**, Lycett. T.
J. Lycett, Ann. Mag. Nat. Hist., vol. vi., 1850, p. 417 ; Proc. Cotteswold Nat., vol. i., 1853, p. 78.
Inferior Oolite. [5357] Leckhampton.

**Trochus pileus**, Lycett. T.
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# INDEX.


## A

Aberfeldy, 106.
——— Green Beds of, 53.
Aberglasney, 45,
Aberlady, 126, 127, 129.
*Acanthodes Wardi*, 14.
Achddu Mill, 181.
Agricultural Notes, 23, 147.
Ailsa Craig Rock, 140, 141.
*Alces machlis*, 24, 62, 207.
Allen, H. A., 61, 217.
Allestree, 10, 17.
Allestree Farm, 19.
Allival, 110.
Allt-Cystanog, 52.
Alluvium, 23, 83, 92, 93, 104, 127; of Thames, 207.
Ambergate, 8, 10, 12.
Ammanford, 184, 186, 187.
——— — Colliery, 185, 187.
——— Disturbances, 48.
Amman Valley, 187.
Amphibolite, 88.
Analyses of coals, 189–191.
Anderson Dr. T., 150.
Anthracitisation, 49, 189–191.
*Anthracomya*, 12.
——— *Phillipsi*, 14, 15.
Anticline of the Carboniferous Rocks, 8, 9.
Antrim Road, 140.
Aplite, 31, 98, 100.
Arbont, 45.
Ardfern, 82.
Ardmaddy Bay, 77.
Ardrishaig, Phyllites of, 69.
Argyllshire, 64, 65.
Arran, 65.
Arsenic, 38.
Arthur's Seat, 65, 119.
Ashdown Sand, 196.
Ashton, 168, 170.
——— to Exeter, New Railway, 170.
Ash, volcanic pumice from, 60.
Askival, 110.
Atholl Forest, 64, 65.
Augen-gneiss, 85, 89.
Ault a Mhullin, mineral from, 58.
Aureole, granite, 25, 26, 32, 36–38.
Aveley, 202.
*Avicula contorta*-shales, 192–194.
*Avnculopecten*, 15, 16.
Avonmouth, 162.
Awsworth, 13.
Axinite, 35, 166.
Ayrmer (Armour) Cove, 161–165.
Ayrshire, 65.

## B

Babbington, 13.
Bailey, E. B., 65–76, 81, 82, 120 124, 126–129.
Baker, Mr., 192.
Ballachulish, 76.
Ballinluig, 106.
Balloon Wood, 19.
Ballyhill, 141.
Ballymacoss, 148.
Bampton Quarries, 170.
Banc-y-Mansel, 42, 43.
Bangor, 144.
Barbados, Pumice from Volcanic ash which fell at, 60.
Barbreck, 66.
Barium sulphate, 18.
Barkeval, 110.
Barnes, W. D., 30, 36.
Barratt, W., 63.
Barrow, G., 2, 6, 93–95, 101–103, 108, 109, 112–115, 122–124, 127, 128.
Baryto-celestite, 60.
Basaltic Uplands, 138–140.
Baveno, Laumontite from, 59.
Bawden, 34.
——— Cottage, 37.
Beacon Cove, 29.
Beacon Point, 163.
Bedding in granite, 31–33.
Bedfont, West, 206.
Beer Alston, 169, 170.
Beesands, 163.
Beeson grit, 163.
Beeston, 20, 22, 23.
Beinn Alder, 103.
——— Vrackie, 102.
Belfast Town and District, 138, 146.
——— Lough, 138, 142, 143, 146.


Digitized by Google

Belfast Museum, 140.
——— Naturalists' Field Club, 140.
——— Sheet index to, 139.
Belnahua, 67.
Belper, 8–11.
Belperlawn Colliery, 11.
Belt, T., 207.
Bemrose, H. H. A., 62.
Bennett, F. J., 148, 149.
Ben-y-Ghloe, 103.
Berry Head, 160.
Bettws Fault, 182, 184, 188.
Bickington, 167, 168.
Bigbury Bay Section, 160, 165.
Big Vein, 186, 187.
Birnam, 104.
Bishopsteignton, 169.
Bissoe, 38.
Bituminous Shales, 198.
Black Grit, 47.
——— Rocks, 43, 46.
——— Shale or Clod Coal, 11–13.
Blackstaff river, 143.
Blackwater, 87, 89.
Blaenau Colliery, 185.
———— -mawr Disturbance, 188, 189.
Blair-Atholl, 101.
Blake, J. H., 149.
Boconnoc, 165.
Bodmin Moor granite, 166, 167.
———— Road, 165.
Bonar Bridge, 152.
Borough Island, 162.
Bottom Coal, 11,12.
Boulder Bed of Schichallion, 54.
Boulder-clay, 20–22, 24, 82, 92, 127, 139, 140, 142–148, 200.
Boulders, 21, 22.
Bovey Tracey, 167–169.
———————— Railway cuttings toward Lustleigh, 168.
Bowie, K., 210.
Box Fault, 174, 175.
Braddock (Broadoak), 165, 166.
Braid Hills, 119.
Bramcote, 18, 19.
———— Hills, 13, 20.
Brass Vein, 187.
Breadsall, 10, 21, 23.
———— Moor, 9.
———— Station, 17.
Brecciation of Cornish veinstones, 155.
Breccia at the base of the Bunter, 18; of the Magnesian Limestone, 16.
Brent, 166, 167.
Brentford, 204.
Brentwood, 201.
Brickearth, 23; Thames Valley, 24, 204.
Brick-making, 146.
Brixham, Coast south of, 164.
Broadoak Colliery, 171, 174.
Brondini, 52, 184, 189.
Brookhill, near Kingswear, 165.
Broomhill Wood, 19.
Brown, J. Allen, 207.
Brownqueen, 166.
Brownstones, 41, 42, 46, 52.
Broxmouth, 122.
Broxtowe Wood, 13.
———— Fields, 19.
Bryn-bargod, 183.
Bryn-gwili fault, 183, 188, 189.
Bryn-serfyll Fault, 174, 183.
Bryn-yr-odin, 42, 45, 46.
Buckland Hollow, 12.
Building Stone, 23, 37, 38, 52.
Bungay Lode, 34.
Bunter, 17–19.
Burry Port, 51, 175, 182.
Bute, South, 65.
Bynea, 174.
Byre Burn, 211

## C

Cadell, H. M., 115.
Cae Colliery, 171, 175.
Cae Duke, 173.
Caedu Pit, 177.
Caerbryn Colliery, 185–187.
Cailleach head, Loch Broom, Phosphatic nodules from, 56.
*Calceola*, 29.
Calciferous Sandstone 120, 121—124, 209.
California, 186.
Camborne, 31, 38, 39.
Cambrian, 107.
Camelford, 167.
Cannel Coal, 13.
Canonbie Coal-field, 209.
Cantrill, T. C., 2, 40–42, 44, 50, 149, 170, 182–189.
Caol Scotnish, 70.
*Carbonicola*, 12–16.
Carboniferous, 8–16, 30, 64, 65, 115, 167.
———— Limestone, 42, 43, 45–47, 52, 144, 192–194.
———— —— Series, 125–126.
———— —— Phosphatic nodules in, 56.
Carnaghliss, 141.
Carnarfon Pit, 177, 178.
Carn Brea, 38.
—— Menelez, 30.

Digitized by Google

Carmarthen, 52, 53.
Carmarthen Bay, 170.
Carmel, 45.
Carsaig, 113.
Carway Vein, 188.
Cassiterite, 31–33, 38–40.
Castell Cennen, 45, 46.
Castle Canyke, near Bodmin, 166.
Castle Espie, 144.
Caswell Bay, 47, 48.
Catalogue of Fossil Gasteropoda and Scaphopoda, 217.
Catstone Hills, 19.
Cefn-arda shaft, 171, 172.
Cefn-y-bryn, 42.
Cenrhos Rock, 52.
Cenrhos Vein, 52, 181.
Cement stone Group, 121.
Chacewater, 25.
Chaddesdon Common, 21.
Chalky Boulder-clay, 20, 21.
Challaborough, 161, 162.
Champernowne, 166.
Chapel Rock, 36.
Chemical work, 56.
Chertsey, 203.
Chiastolite, 37.
Chilwell, 20, 22, 23.
Chipping Sodbury, 192; Barytocelestite from, 60.
Christen, Madame, 144.
Chromium in rocks, 60.
Chudleigh, 169.
Chyandour, 35.
Cîb Valley, 41.
Cille Colliery, 179, 180.
Cille Seams, 179, 180.
Cilsân, 41.
Cil-y-maenllwyd, 180.
Cinderhill, 16.
Clacton, 206.
Clady water, 141.
Clay 58.
Clay Cross, 15.
—— Vein, 52.
Clifton Colliery, 15.
Cligga Head, 31–34, 36, 37.
Clochyrie, 174.
Clod or Black Shale Coal, 11-13.
Close Maxwell, Rev., 145.
Clôs-isaf, 183.
Clough, C. T., 1, 5, 64, 84-87, 89–91, 93, 120–122, 125–128, 150–154.
Clyn-gwernen, 174.
Cnoc-an-t'Saic, 152.
Coal-fields, 3.
Coal in the Millstone Grit, 11.
Coal Measures, 8, 9, 11-16, 44, 46, 209.
Coal-Plants, 62, 210.
Coal-seams, 11.
Coals west of Ammanford, 186, 187.
Cockburnspath, 64, 121, 125, 127, 128.
Cockpithall, 183, 189.
Cockridge Point, 162.
Cockshot rock, 187–189.
Coddon Hill, 167.
Coed-cyw Mill, 183.
*Coelacanthus*, 14.
Colliery, 188.
Collin Glen, 142.
Collins, J. H., 3.
Colnbrook, 24.
Colour-printed maps, 6, 7.
Comber, 144.
Conglomerate of the Bunter, 19; in Carboniferous Limestone, 43; of the Millstone Grit, 11.
Connel Ferry, 76.
Conn's Water, 143.
Constantine, 30, 31.
Constituents of Culm greywacke, 168, 169.
Contact metamorphism, 166.
Coombe Rock, 206.
Coombeway, 169.
Copper ores, 32.
Corals, 160–162, 164, 165.
Core Harbour, 121.
Corn Brea, veinstones, 158.
Corn-hwrdd, 183.
Cornstones, 42.
Cornwall, 25–40.
Correlation Table, 186, 187.
Cossall Colliery, 13.
Cotty's Point, 26.
Coulmore, Ross-shire, Nepheline from, 57.
Coxbench, 10.
Cox Tor, 167.
Crabrock Point, 164.
Crags formed by the Bunter, 19.
Craig, E. H. Cunningham, 6, 54, 84, 89, 90, 93, 96–100, 102, 103, 115, 119.
Craig-lon, 51, 182.
Craignish, 66, 75, 81–83.
———— Phyllites 67–69.
Craigs District, 86, 91.
Craig-y-geifr, 183.
Crampton, C. B., 65, 66, 84–87, 89–93, 120, 126, 127, 129, 150.
Crayford, 205, 206.
Creepinghole Point, 28.
Cretaceous, 113.
Cretaceous Rocks, upper, 139.
Crich, 8, 9.
Crinan, 65, 66, 70, 74, 75.
Croft Wood, 17.
Cross-courses, 32, 40.
Cross Hands, 48, 50, 183, 184, 187–189.
Crownhill Bay, 161, 165.
Crowstones, 10.

Digitized by Google

Crush-breccias, 108.
——— conglomerates, 30.
Crystalline Schists, 150.
Culm chert, 169.
—— greywacke, 167.
—— outliers between Newton Abbot and Ipplepen, 168, 169.
Cumberhill, 10, 17.
Cumbraes, 65.
Cwm-bach, 175.
—— Capel, 52.
—— Ierman, 181, 182.
—— Lash, 185.
—— mawr Colliery, 180.
Cynheidre, 184, 189.

## D

Dafen, 174.
Dale Mill, 12, 17.
Dalnaspidal, 98.
Dalton, W. H. 206.
Dalwhinnie, 104.
Darnacombe, 162.
Dartmoor, 167, 169.
Dartmouth Slates, 27, 30, 160, 162, 164, 165.
Davis, and Co., E., 64.
Dawkins, Prof. W. B., 207.
Dawson, C., 195.
Deanich District, 84, 89, 90, 93.
Deeley, R.M., 22.
Deep Hard Coal, 11–13.
Degnish, 60, 75, 77.
———— Limestone, 70.
De la Beche, Sir H. T., 7, 27, 32.
Denby, 9, 12.
——— Colliery, 12.
Depression, Pre-triassic, 138, 144.
Depth o' Lumb, 10.
Derby, 20, 23.
——— Waterworks, 22, 23.
Derbyshire Coal-field, 14.
Derwent Valley, 23.
—— —— gravels, 22.
Devon, 30, 160, 167.
Devonian, 3, 26–30, 38, 160, 167.
*Dicranograptus*-shales, 41.
*Didymograptus bifidus*-beds, 41.
Diorite, 79.
*Discina*, 14.
Divis Mountains, 139, 140.
Dixon, E.E.L., 25, 26, 48, 50, 148, 149, 170, 183, 184.
Dobbs Hill Plantation, 9.
Doddiscombleigh, 168.
Doe Hill, 15.
Dolcoath, 38, 40.
Dolcoath, veinstones, 155.
Dolerites, 81.
Dolomitic Limestone Mottled 59.
Dolomitisation, 43.
Dolwen Point, 43.
Dores, 90, 92, 93.
Dousland, 166.
Drift. See under Glacial.
Drumlins, 141, 144, 145.
Dry Gap, 143.
Dryslwyn, 41, 45.
Dublin District, 140, 141.
Duffield, 10.
———— Bank, 21.
Dunardry, 70.
Dunbar, 121, 125, 127, 128.
Dundonald, 144.
———— Valley, 144, 145.
Dunmurry, 142, 148.
Duntelchaig, 90.
Dyffryn, 177.
Dynevor and Maes-y-cwarau, 188.

## E

Easdale Slates and Limestones, 69, 70.
East Cornwall, 160, 165, 167, 168.
———— Looe, 160, 165.
Eastern Drift, 20–22.
Economics, 23, 84, 93, 115, 117, 146.
Efford, 167, 169.
Eifelian, 166, 167.
Eigg, 64, 65, 106, 108, 113, 114.
Eilean Dubh Mor, 73.
Elk, 24, 62, 207.
Ell Coal, 11–13.
Elvans, 30, 31, 34, 35, 37–39, 166
Emlyn Colliery, 183, 185–187.
Enfield, 24.
Entomostraca, 12.
Eocene, 24.
*Eophrynus* in South Wales, 62.
Epidiorite, 66, 68, 75, 87, 102.
Erewash Valley, 9, 11, 13, 20, 21, 23.
Erw-wastad-fach, 183.
Esker Gravels, 142, 146.
———— Ridges, 142.
Essex, Drifts of, 200.
Estuarine Clays, 146.
Etruria Marls, 15.
Evans Pit, 177.

## F

Falmouth Series, 25, 26, 36, 161.
Fairlight Clays, 196.
Fairlop Plain, 194.
Farewell Rock, 44.
Farcote Gill, Westmorland, Phosphatic nodules from, 56.
Farlawn, 9.
Farley, 168.
Faults, 8, 9, 13, 19, 20, 30–32, 39, 40, 42, 44–49.

Digitized by Google

Faults, Age of some, 175.
Felin-foel, 175.
Felsite, 81, 96, 168.
Felstone, 100.
Feltham, 24.
Fern Cavern, 29.
Ffairfach Grit, 40, 41.
Fforest, 52, 173.
Fiery Vein, 172, 173, 177.
Fife, East, 65.
Fireclay, 31.
Fish Cellars, 162.
Fisher, E. R., 185.
——— Rev. O., 206.
Fish scales, etc., 12, 14.
Fistral Bay, 29.
Fladda, 67.
Flett, Dr. J. S., 3, 40, 47, 53, 101, 149, 150, 154.
Foel Gastell, 50.
Folds, 8, 9, 184, 185.
Foraminifera, 140, 143.
Ford Plantation, 166.
Fossil Gasteropoda and Scaphopoda, Catalogue of, 217.
Fossil shells in coal-roof, 187.
Fossils of the Carboniferous Rocks, 10, 12–15; Devonian, 28–30; Old Red, 27–29.
Foster, Dr. C. Le Neve, 33.
Fowey, 30, 165.
Fox, B., 161, 164.
—— Howard, 27, 63.
Freeman, Mr., 22.
Fritchley, 8.
Fruit cones in the Coal Measures, 12.
Furnace, 181.
——— Coal, 11-13.

## G

Gabbro, 110.
Gaick, 64, 65, 93, 98, 103.
Galgeth, 166.
Gannel, 30, 36.
Gappagh, 169.
Garbh Allt, 152, 153.
Gareg-gwenlas, 43, 52.
Garlton Hills, 65.
Garn, 43, 49, 52, 183.
Garnets, 36.
Garn Swllt Vein, 189.
Gas, Natural, 195.
Gasteropoda, Rhætic and Jurassic, 217.
Gedling, 15, 16.
——— Colliery, 13.
Geikie, Sir A., 112, 115, 149.
——— Prof. J., 207.
Gelli-gwernen, 183.
Gelli Pit, 174.
Gerrard's Cross, 24.
Gibsonstown, 141.
Gibson, W., 4, 8, 9, 12–21, 148, 149
Gifford, 124, 126, 127.
Gilbertite, 33.
Glacial Beds, 20–22, 82, 90, 102, 113, 117, 118, 127, 139–146.
—— Lake of the Tay, 104.
Glaciated Rock Surfaces, 145.
Glen Banchor, 100.
Glengormly, 142.
Glen Gour, 76.
—— Tilt, 102.
—— Tromie, 98.
—— Truim, 64, 65, 100.
—— Urquhart, 89, 90.
Glynn, 166.
Glyn Wallis, 172, 183.
Gneiss, 88, 140.
Godrevy, 26.
Goitre-wen, 183.
Golden Vein, 173, 174.
*Goniatites*, 10, 12, 15, 16.
——— *Spiralis*, 168, 169.
Goodchild, J. G., 138, 207.
Goonhavern, 35.
Goonzion Down, 166.
Gorebridge, 118.
Gorseinon, 171, 172, 183.
——— Fault, 188.
Gorsgôch, 186, 187.
Gors-Lâs, 52.
Gower, 42, 43, 47.
Gowerton syncline, 179.
Graigola Vein, 172.
Grampound, 25.
Granite, 30–34, 36, 37, 39, 40, 79 98, 100, 111, 140, 150.
Gransha River, 145.
Grantully, 106.
Gravel, 22, 23, 143–145.
—— ridges, 142.
Gravelly drift, 141.
Grays, 202, 204, 205, 206.
Great Cross Course, 40.
—— Estuarine Series, 108.
—— Flat Lode, 39, 40.
—— Morfa Pit, 50, 178, 179.
—— Oolite, 108.
Greece, Ores of, 64.
Green beds, 53.
Green Island, 34.
Greenstone, 29, 30, 35, 36.
Greisen, 32–34.
Grindstones, 23.
Grongar East, 45.
Grovesend Veins, 170–173.
Gun Lane Colliery, 11, 12.
Gunn, W., 64, 84.
Gwal-y-hwch, 52.
Gwendraeth Disturbance, 42, 45–48.

Digitized by Google

Gwendraeth Fach Valley, 42, 45, 46, 49, 50.
Gwili Valley, 49, 50, 173, 184, 188, 189.
Gwr-aeth, 175, 180.
Gyscwm Vein, 52, 181, 182.

H

Haddington, 124, 126, 127.
Hagg, 18.
"Hälleflinta," 37.
Hallett, R., 198.
Hampton, 203–205.
Hams Sand, 162.
Hanover Cove, 34.
Hanworth, 205.
Harefield, 202.
Harker, A., 2, 5, 6, 106–111, 113, 114.
Harlington, 24.
Harmondsworth, 24.
Hayle Sandstone, 3, 25, 26.
Hazlewood, 10, 21, 22.
Heacham, 63.
Heage, 12.
Heathfield, 195–199.
Henderson & Sons, Messrs., 39.
Hendre Fault, 185, 188.
Hendy, 173.
Heston, 24.
Higher Hill Farm, 166.
Highland Metamorphic rocks, 1, 65, etc.
High level valley gravels, 22.
High Wycombe, 24.
Hillingdon, 202.
Hill, J. B., 25, 30, 31, 38, 39, 150.
Himlack Stone, 20.
Hinch, J. de W., 62.
Hind, Dr. Wheelton, 4, 13, 14, 129, 137.
Hinton, M. A. C., 207.
Hinxman, L. W., 1, 84, 87–90, 92, 93, 100, 101, 104, 115, 118, 149.
Hisley, 168.
Hoist Point, 160, 162, 165.
Holbrook, 9–12.
Holme Nook, 23.
Holmes, T. V., 24, 194, 200.
Holy Well, 30.
Holywell Bay, 36.
Holywood, 143.
———— Glen, 143.
Home Office, mine plans in the, 38, 39.
Honey Cors Farm, 43, 52.
Hope Headland, 163.
Horeb, 47, 180.
Hornblendites, 87.
Hornblende schists of sedimentary origin, 53.
Hornchurch, 24, 202.
Horne, Dr. J., 64, 84, 90, 92, 93.
Hornfels, 150.
Horse Rock, 28.
"Horses," 40.
Horsley, 9, 12, 21.
——— Carr, 9.
——— Fault, 9, 12.
——— Woodhouse, 21.
Hospital Coal, 12.
Howe, J. A., 24, 64, 194, 202
Hughes Vein, 171, 179.
Hull, Prof. E., 18.
Hunter, W., 62.

I

Ice-sheet, 146.
Ickenham, 24.
Ideford, 168.
Ilford, 24.
——— Railway, 194.
Ilsington, 166, 167.
Inchbae, 86.
Inferior Oolite Gasteropoda, 222.
Inverness-shire, 64, 65, 84.
Ipswich, 7.
Ireland, 138.
Ironstone, 36.
Iscoed, 46.
Isles of the Sea, 71, 74.
Isleworth, 204, 205.
Iver, 202.
Ivybridge, 166.

J

Jamieson, T. F., 103.
Jockie's Syke, 215.
Joints, 30, 34.
Jura, 66, 75.
Jurassic, 5, 108, 139.

K

Kelsey Head, 29, 30, 35.
Kennard, A. S., 207.
Kentallenite, 76.
Kerrara, 78; Old Red Conglomerates of, 78.
Keuper, 192, 194.
———— Marl, 20.
———— Sandstone, 19.
Kidston, R., 5, 62, 129–137, 209.
Kidwelly, 50.
Kilbourne, 21.
————Station, 9, 12.
Kilburn Coal, 9, 11, 12, 13.
Kilchoan Bay, 77.
Kildermorie, 86, 151.
Kilmartin, 66, 69, 75.
Kilmelfort, 65.

Digitized by Google

Kilmory, 114.
Kilroe, J. R., 138, 141, 142, 145, 146.
Kimberley, 13, 16, 17.
Kimeridge Clay, 198, 199.
Kingsbridge district, 161.
———— Estuary Sections, 166.
Kinloch, 106, 114.
Kintyre, 65.
Kitchin, Dr. F. L., 61.
Knapdale, 64.
Knowle Farm, 208.
Kynaston, H., 65, 67, 68, 72–82, 93, 95, 96, 130.

## L

Lagan River, 138, 142, 143, 145, 146, 148.
——— Valley, 138, 145.
Laleham, 24.
Lammermuirs, 64.
Lamplugh, G. W., 6, 138–140, 145, 146.
Lamprophyre, 81, 95, 96, 100.
Land's End area, 25, 39.
Lanhydrock, 166.
Lanreath, 166.
Laugharne, 42, 43, 52.
Laumontite from Baveno granite Quarries, 59.
Lawell House, 169.
Lead mining, 52.
Lea Valley, 24.
Le Grand and Sutcliff, Messrs., 196.
Lelant Towans, 26.
Lenton Park, 19.
*Lepidodendron*, 12.
Lewisian gneiss, 1.
Lias, 192–194.
—— Gasteropoda and Scaphopoda, 217.
Library, 64.
Ligger, 28, 30.
Limestone, Carboniferous, mottled, 59.
*Lingula*, 14, 15, 16.
Lisburn, 142, 148.
Lismore, 71.
Little Eaton, 9, 21–23.
Liverton, 168.
Llanarthney, 41, 45, 49.
Llandilo Flags, 40, 41, 45.
———— Limestone, 52.
Llandilo-rhwnws, 52.
Llandovery beds, 41.
Llandybie, 50, 182.
Llandyfaelog, 46.
Llanedy, 50, 173, 184, 188, 189.
Llanelly, 49, 51–53, 170, 171, 174, 175–8, 182.
Llanelly Syncline, 47, 48, 175–6, 179, 180, 182.
Llangathen, 45.
Llangennech, 174.
Llannon, 50, 182–184, 188, 189.
———— Disturbance, 47, 48, 188.
Llanstephan, 42, 43, 46, 49.
Lletty Grit, 41.
Lliedi Valley, 49, 50, 52, 53.
Llwydcoed Veins, 189.
Llwyn-y-piod, 175.
Llwyn-yr-hâf, 187.
Llynfi Rock, 189.
Llyn-llech-owen, 52.
Loam of Thames Valley, 204.
Loch Avich, 78.
—— Craignish, 66.
—— Garve, 87, 89.
—— Glass, 87, 91.
—— Gorm, 89.
—— Linnhe, 64, 76.
—— Melfort, 76.
—— Ness, 90.
—— Shiel, 64.
—— Sween, 66, 70.
Lodes, 30–34, 38–40.
Loess, 204, 205.
Logan, Sir W. E., 181.
London District, 6, 24.
———— Thames Valley Deposits, 199.
Longcliff Cave, Derbyshire, 62.
Long Eaton, 23.
Long Sands, 164, 165.
Longstone, 162, 163.
Looe Beds, 160, 164, 166, 167.
Lorne, 64.
Lostwithiel, 166, 167.
Lough Neagh, 141.
Loughor Valley, 49, 170–175, 177, 179, 183, 184.
Lower Culm-measures, 166–170.
———————— succession, 168.
Lower Devonian, Paignton Anticline, 160.
———————— succession, 160, 167.
———————— Torquay Anticline, 160.
Lower Hard Coal, 12.
———— Hartshay, 8, 9.
———— Kilbourne, 9.
———— Limestone Shales, 42, 43.
———— Main or Tupton coal, 11, 13.
———— Pumpquart Vein, 185–187.
Lowestoft, Well-boring at, 62.
Luing, 69, 75, 81.
Lunga, 66, 67, 70, 73, 75, 81, 82.
Lunn R., 138.

## M

Mabe, 30, 31.
MacAlister, D.A., 3, 38–40, 154.
Macconochie, A., 25, 129, 130, 132 135, 138, 209, 211, 214.

Digitized by Google

Mach-ynys, 51.
MacMahon, General C. A., 167.
Maes-llydan, 184.
Maes-y-fallen, 40.
Magnesian Limestone, 17.
Maidenhead, 203, 204.
Makeney, 10.
Malone, 143.
Man Sands, 164, 165.
Mansfield, 15.
Mapperley Colliery, 13.
Maps, 148–150; Colour-printed, 6, 7.
Marehay, 9.
Marginal character of the Permian and Trias, 17–19.
Marine bands in the Coal Measures, 14, 16.
Marine Shells, 140.
Maudlin, 166.
Mayfield, 195, 198.
McHenry, A., 138, 144.
McKillop, George F., 116.
Meadfoot group, 160, 164, 166, 167.
Meall na Speireig, 91.
*Megalichthys*, 12.
Memoirs, 6, 7, 148, 149,
Metamorphic Rocks, 65, 84–89, 93.
Metamorphism, 25, 26, 32, 36–38, 68.
Metasomatism, 31, 33.
Mica-porphyrites, 81.
Mica Trap, 36, 37.
Middle Culm-measures, 168–170.
——— Devonian, 164, 166, 167.
Middleton Hall, 41, 44, 45.
Middleton, R.E., 62.
Midland District, 6, 8.
Midlothian, 64.
Milford, 10, 11, 21.
Millendreath, 160.
Millstone grit, 8–11, 44, 52.
Milltown, 142.
Mines, 3, 30–34, 38–40.
Minnette, 36, 37.
Mispickel, 32.
Mitchin Hole, 47.
Moine Schists, 1, 2, 55, 150.
Monckton, H. W., 207.
Moose, 24, 62, 207.
Moraines, 82, 91, 92, 104.
Moreb, 175, 180, 181.
Morlais Colliery, 174.
——— Valley, 49, 50, 174, 183, 184.
——— Fault, 188, 189.
Morley, 12, 17, 18, 19, 21.
—— Moor, 9.
Morris, George, 62.
Mottled Clay, 58.
——— Limestone, 59.
Moulding Sand, 23.
Mountain Colliery, 171–174.
Mountfield, 195, 199.
Mount Pleasant, 9, 12.
Mouthwell, 163.
Muff, H. B., 65–68, 72, 75, 81–83, 138, 141, 144, 145.
Mugearite, 112.
Mull, 106, 113.
Museum of Practical Geology, 64
Mylonite, 47.
Mylor Series, 25, 26.
Mynydd Bettws, 188.
——— Sylen, 184, 189.

## N

Nant-garedig, 52, 184.
Neill's Hill, 144.
Nelson's Tower, 44.
Nepheline, 57.
——— alteration product after, 58.
Netherfield, 195.
Nether Heage, 11, 12.
*Neuropteris*, 12.
New Cross Hands Colliery, 185, 187.
Newdowns Head, 34.
New Drive (Torquay promontory) 164.
New Lodge Level, 181.
Newlyn East, 26, 34, 35.
Newquay, 26–30, 35–38, 63.
Newton, E. T., 24, 61–63, 150, 207.
Newtonmore, 65, 100.
Newtown Ards, 144.
Newtownbreda, 143.
Nibble and Clink Colliery, 11.
Nine-fathom Fault, 175.
Nodules, phosphatic, 56.
North Berwick, 122, 127, 128.
North Crop, 184–189.
North Staffordshire, Comparison of the Coal Measures of, 14.
Nottingham, 15, 19.

## O

Oakerthorpe, 8.
Ochre, 38.
Ockendon, North, 202, 203.
——— South, 24.
Oil-shales, 4, 115, 198.
Old Castle Colliery, 175, 176, 178.
Oldchard, 168.
Oldhamstocks, 121.
Old Red Sandstone, 2, 26–30, 41, 42, 45, 46, 52, 65, 76–79, 89, 90, 192, 193.

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Olivine-anorthite rocks of Rum, 110.
——— basalts, 81.
—— —— dolerite, 112.
Ordovician rocks, 40, 41, 44, 45.
Ormeau Park, 143.
Ormsay, 73.
Orrin, 88.
Overlap of the Trias, 17.
Overthrust faults, 27–30, 46, 47, 48, 176, 179, 180, 185, 186, 188, 189.
Overton Mere, 43.
Oxfordian, 108, 109.
Oxwich, Mottled Limestone from, 59.

## P

Padderda, near Menheniot, 169.
Padleywood Farm, 15.
Palæolithic gravels, 7, 205, 207.
Palæontological work, 61–63.
Pantyffynnon, 186, 189.
Pant-y-ffynnon old colliery, 183.
Pant-y-llydu-fach, 179, 180.
Pant-yr-yn, 183.
Park Colliery, 185, 187.
Paving stones, 23.
Peach, Dr. B. N., 2, 64–82, 106, 115, 119, 129, 130, 132, 135, 137, 149, 150.
Peat, 83, 92, 147.
Pebble Beds, 17–19.
Pebbles in the Millstone Grit, 11.
Peebles-shire, 64.
Peek Hill type, 166, 167.
Pegmatite, 94, 98, 99.
Pembrey, 49, 170, 175, 182.
Pencarrow Head, 165.
Pencoed Colliery, 175.
Pendine, 42–44.
Pendleside Series, 10.
Pengrys Fault, 174.
Penhale, 27, 30.
Penicuick, 118.
Pen-lan, 174.
Penlan Colliery, 179.
Pen-llwyn-gwyddau, 183.
Pennant quarries, 52.
Pennant Sandstone, 187, 188, 189
Pentire Point, 29.
Pentland Hills, 65, 119.
Pentre-hardd, 183.
Pentrich, 8, 11.
Pen-y-cwm-uchaf, 183.
Pen-y-fan, 174, 177, 178.
Pen-y-gaer Fault, 176.
Pen-yr-heol, 174.
Penzance, 35.
Peridotite, 88, 110.
Permian, 16, 17.
Perran, 30, 36, 37.
——— Coombe, 34, 35.
——— Shales, 26.
Perranporth, 26, 34, 35.
Perranzabuloe, 26, 30.
Perridge Tunnel, 170.
Petrographical Work, 53.
Philipston, 116.
Phosphatic nodules, 29, 56.
Picrite, 110.
Pilchard Inn, 162.
Pilsley Junction, 15.
Piodau Veins, 187.
Piper Coal, 13.
Pitlochry, 65.
Pitton Mill, 43.
Plants in alluvium, 23; in Coal Measures, 12; in Old Red Sandstone, 79; in Carboniferous, 118.
Plas-isaf Fault, 174, 183.
Pleistocene, 20–22, 24.
Plymouth Coast Section, 160, 161, 165.
——— area, 167.
Pocock, T. I., 24, 148, 199.
Pollard, Dr. W., 29, 191, 198.
Pontardulais, 171, 172, 173, 183.
Pont Lash Colliery, 185, 187.
Pont-y-clerc, 183, 185–187.
Pontyclerc Overthrust, 185.
Porkellis Moors, 38.
Porphyrite, 81.
Port Eynon, 43.
Porth, 28, 29.
Porthtowan, 26.
Porth-y-rhyd, 45.
Portland Beds, 198, 199.
Portscatho Series, 25, 26, 37.
Portwrinkle, 162.
*Posidoniella*, 10.
Posidonomya, 168, 169, 170.
Postglacial, 22, 83, 93, 104, 114, 127, 146.
Poundsford, 197, 198.
Praeger R. L., 146.
Prestonpans, 64.
*Prestwichia* in South Wales, 62.
Prestwich, Sir J., 201, 204.
Pre-Triassic disturbances, 47, 48.
Priest's Hill, 141.
Probus, 25.
*Pteraspis*, 27–29, 161, 162, 164.
*Pterinopecten*, 15.
Pumice from Volcanic ash, 60.
Purbeck Beds, 196–199.
Purdysburn, 145, 148.
Purfleet, 204, 205.
Pwll, 170, 175, 176, 180.
Pyroxenite, 88.

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## Q

Quarndon, 10, 17.
Quarries, 37, 38.
Quartz-albite veins, 162.
Quartz-felsite, 111.
Quartzite, 140.
——— of Jura and Islay, 73; Divisions of in Scarba, 73; unconformability at base of, 71.
Quartz-porphyry, 35, 94, 95, 99, 100, 112.

## R

Raddicombe, 164.
Ragwen Point, 44, 49.
Railway cuttings, 7; Great Central, 24; Great Eastern, Woodford and Ilford, 194; Great Western, 24, 192; Metropolitan, 24.
Raised Beaches, 49, 83, 93, 114, 127, 146.
"Rakes,' 11.
Ramsay, Sir A. C., 15.
Reading Beds, 24.
Reading, Clay from, 58.
Recent deposits, 22–24, 146.
Redhill, 142.
Redruth, 31, 38, 39.
Red Shales, 214.
Red Vein, 184, 187, 188.
Reed, F. R. Cowper, 137.
Reid, C., 3, 25–29, 35–38, 63, 148–150, 206, 207.
Reynolds, Mr., 192, 193.
Rhætic, 192–194; Gasteropoda, 217.
Rhondda No. 2 Vein, 188, 189.
Rhôs Colliery, 185, 186, 187.
Rhossili Hill, 42, 43.
Richmond, Surrey, 203, 205, 207.
Ridgeway, 12.
Riebeckite rock, 140.
Ringmore, 161–165.
Risley Park, 21.
River Terraces, 22, 202.
Road metal, 37, 38, 52.
Roberts, Mr., 170.
Roche, 38.
Rock-basins, 82.
Rock Castle, 186.
Rock Vein, 185–187.
Romford, 24, 200.
Roof of the Coal Seams, 12.
Rosenbusch, Prof. H., 36.
Ross-shire, 64, 65, 84, 150.
Rottenstones, 43.
Rowanburn, 210, 214.
Ruislip, 24.
Rum, Isle of, 3, 5, 64, 65, 106, 109, 114.
Rushyhill River, 141.

## S

St. Agnes, 25, 26, 30, 31, 33, 38.
St. Allen, 26, 36.
St. Austell Granite, 165, 166.
St. David's Colliery, 171, 172, 174.
St. Day, 25.
St. Erney, 168, 169.
St. Mellion, 168, 169.
St. Neots, 166.
St. Pierre, Destruction of, 55.
St. Piran, 35.
St. Vincent, Eruptions in, 55.
Saltash District, 167.
Salterwood Colliery, 12.
Sand-dunes, 35.
Sandiacre, 19, 23.
Sands, 23; stratified, 140, 142, 143
Savernake Forest, 207.
Sawmill, 12.
Scabbacombe Sands, 165.
Scalpay, 61.
Scaphoda, Liassic, 218.
Scapolite, Amphibolite, 54.
——— hornblende gneiss, 55.
Scarba, 66, 70, 75, 81, 82.
Schichallion Boulder Bed, 54.
Schists, 1.
Schorl, 31–34, 35, 37.
Scotland Farm, 35.
Scotland, Field Work in, 64, 65.
Scrivenor, J. B., 3, 26, 31–37, 155, 159.
Scythestones, 23.
Section near Clay Cross, 15.
Sedgewell Cove, 162.
Seil, 70.
Senni Beds, 41, 42, 52.
Seymour, H. J., 138, 144.
Shag Rock, 37.
Sharkham Point, 164.
Sharpland Point, 162.
Shells in drift, 140, 141, 144, 145.
—— in the alluvium, 23.
Shepperton, 205.
Sherwood Colliery, 13, 15, 17.
Shuna, 68, 69, 75, 81.
——— Limestone, 70.
"Silica Sand," 44, 52.
Silurian Rocks, 41, 44, 45.
——— Uplands, 138, 139, 144.
Six-feet Vein, 172, 173.
Skerry Sandstone, 20.
Slapton Ley, 163.
Slate Rock, 145.
Smyth, Sir W., 11.
Snettisham Clay, 63.
Soft Coal, 11, 12, 13.
Soils, 147, 148.
Sonning, 62.
Sourton, 167.
Southdown Cliffs, 164.
Southern English District, 7, 25.

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South Wales District, 7, 40.
——— ——— Institute of Engineers, 191.
*Spirorbis*, 12.
Spondon, 21–23.
Springs, 52, 53.
Spurrell, F. C. J., 202, 205–207.
Staddon Grits, 164.
Staines, 24, 62, 203–5.
Stanley's Pit, 51, 182.
Stanllyd Vein, 185–187.
Stanton by Dale, 11, 18, 19.
——— Gate, 12.
Stapleford, 19.
——— Colliery, 13.
——— Hills, 20.
Stem Cove, 29.
Stewart, S. A., 140.
Stickwick, 168.
Stobbs, J. T., 16.
Stony Lane, 11.
Storr, F., 7.
Stradey Fault, 175, 179–181.
Strahan, A., 40, 43, 44, 46–53, 149, 150, 170–183, 189–194.
Strangways, C. Fox-, 8, 11, 19, 20, 22, 23.
Strathconon, 88, 92, 93.
Strathspey, 65.
Strath Tummel, 102.
Stream-tin, 38.
Strelley, 19.
Striæ, 145.
Sub-Wealden Boring, 195, 198.
Sulphate of barium, 18.
Sunnyvale, 163.
Sussex, Natural Gas in, 195.
Sutherlandshire, 64, 84.
Swadlincote, Water supply of, 23.
Sylen, 50.
Syncline in the Coal measures, 9, 15.

## T

Table of Coal seams, 12, 13.
——— Millstone Grits, 10.
Tâf valley, 49.
Tait, D., 78, 129, 130, 132.
Tal-y-clyn, 173, 174.
Tal-y-fan Colliery, 172, 173, 183.
Tamerton Folliott, 169.
Tarannon Shales, 41.
Tavistock district, 168, 169.
Tawell, 166.
Teall, J. J. H., 1, 149, 167.
Terraces of river-gravel, 202.
Tertiary igneous rocks, 81, 109.
Thames Valley deposits, 24, 199.
Thomas, H. H., 2, 40–42, 44, 45, 49, 150.
Thompson, Miss S. M., 144.
Thurgarton boring, 14, 15.
Thurlestone Outlier, 162, 163, 166.
Tilbury, 207.
Tin-bearing veinstones, 154.
Tin ore, 31, 33, 38–40.
Tinsey Head, 161, 163.
Tir-bacas Pit, 177.
Tir Eglwys, 174.
Tir-morfa-fawr, 179.
Tirydail Colliery, 187.
Toby's Point, 161, 162, 165.
Topaz, 33.
Top Hard Coal, 13, 14, 16.
Topley, W., 197–199.
Torcross Coast Section 161, 163 165, 166.
——— type, 162, 164.
Torridonian, 2, 107; phosphatic nodules in, 56.
Torsay, 69, 75, 81.
Tourmaline, 31, 35, 37.
Towan Head, 37.
Towy Valley, 41, 49, 52, 53.
Trachyte, 81, 82, 124.
"Trail," 206.
Transported Material, 139, 140.
Trap wood, 166.
Traquair, Dr., 129, 130.
Trawsdre -ganol, 183.
Treacher, Ll., 62.
Trefanau, 179.
Tregantle, 160.
Trelawne, 166.
Tremadoc Beds, 41, 52.
Trent alluvium, 23.
Tresilian River, 25.
Trevaunance Coombe 34.
Trevellas Coombe, 34, 35.
Trias, 17–20, 138–146, 192–4.
Troed-y-rhiw-goch, 41.
Truro, 25, 38, 39.
Trusham, 168.
Tumble, 183, 188.
Tumble Fault, 189.
Tupton or Lower Main Coal, 11, 13.
Twelve Heads, 38.
Twenty-eight-fathom Fault, 175.
Ty-coch, 175.
Ty-croes, 185, 188.
Type and Figured specimens, 63.
Types of Gasteropoda and Scaphopoda, Catalogue of, 217.

## U

Ugbrooke Park, 168, 169.
Unconformity of the Magnesian Limestone, 16.
Unconformity of the Trias, 8, 17, 19.

Digitized by Google

United Mines, 38.
Upminster, 24, 200, 204.
Upper Devonian, 166, 167, 168, 169.
Ussher, W. A. E., 30, 149, 160.
Uxbridge, 24, 202.

V

Vanadium in Rocks, 60.
Vaughan, Mr., 192, 193.
Veins, mineral, 30–34, 38–40.
Veinstones, Cornish, 154.
Volcanic ash, 29.
——— —— Pumice from, 60.
Volcanic Rocks, north of Loch Melfort, 77; of Glencoe, 78; of Rum, 109; of Eigg, 112; of the Pentland Hills, 119; of North Berwick District and the Garlton Hills, 124.

W

Waddon Barton, 169.
Waldo-Sibthorpe, Col., 64.
Waldron, 195, 196.
Walkhampton, 166.
Ware, W. W., 39.
Warp Clay, 142, 143, 147.
Warren Point, 161, 162.
Watergate Bay, 27–29, 165.
Waterstones, 18.
Water-supply, 23, 52, 53.
Watkeys, Mr., 178.
Watts, I., 7, 195, 196.
——— Prof., W. W., 169.
Waun-gron, 173.
Wealden Beds, 196–199.
Wearde-Efford Beds, Greywacke, 168–170.
Wearde Quay, 167.
Weathering, 26.
Wedd, C. B., 4, 8–12, 17–19, 21–23, 148, 149.
Wendron, 30, 31.
Westcombe Beach, 160.
Western Drift, 22.
West Indies, Recent Eruptions in, 55.
West Kitty, Veinstones, 159.
West Merthyr Pit, 171.
Westmorland, Phosphatic nodules in Carboniferous Limestone of, 56.
Weybridge, 203.
Wheal Basset, Veinstones, 158.
——— Bryan, 26.
——— Enys, 38.
——— Kitty, Veinstones, 159.
——— Prudence, 34, 35, 37.
——— Uny, 40.
——— Vlow, 26, 36.
Whitaker, W., 62, 149, 196, 200.
White Mineral, ? alteration after Nepheline, 58.
White Mountain, 141.
White Rocks, 34.
Wilkinson, B. S. N., 42, 43, 46, 49, 50.
Willett, Dr. E., 207.
Williams and Sons, Messrs. Thos., 170.
Wilson, E., 16, 17, 18.
Wilson, J. S. Grant 4, 6, 59, 65, 75, 76, 93, 102, 104–106, 115–118, 149.
Wimbledon, 202.
Wingfield, 9, 11.
——— Sandstone, 12.
Wokingham, 62.
Wolf Hill, 140.
Wolfram, 32.
Wollaton, 19.
Woodford and Ilford Railway, 194.
Woodward, H. B., 6, 24, 150, 195, 206.
Woolley, 168.
Woolman's Point, 163.
Wrangaton, 166.
Wraysbury, 207.
Wrexham, Boring at, 7.
Wright, J., 140, 143.
——— W. B., 138, 140, 141–143.

Y

Yarmouth Sands, 162.
Yarner Wood, 168.
Ynysarwed Vein, 189.
Yoredale Rocks, 10.

Z

Zelah, 26.

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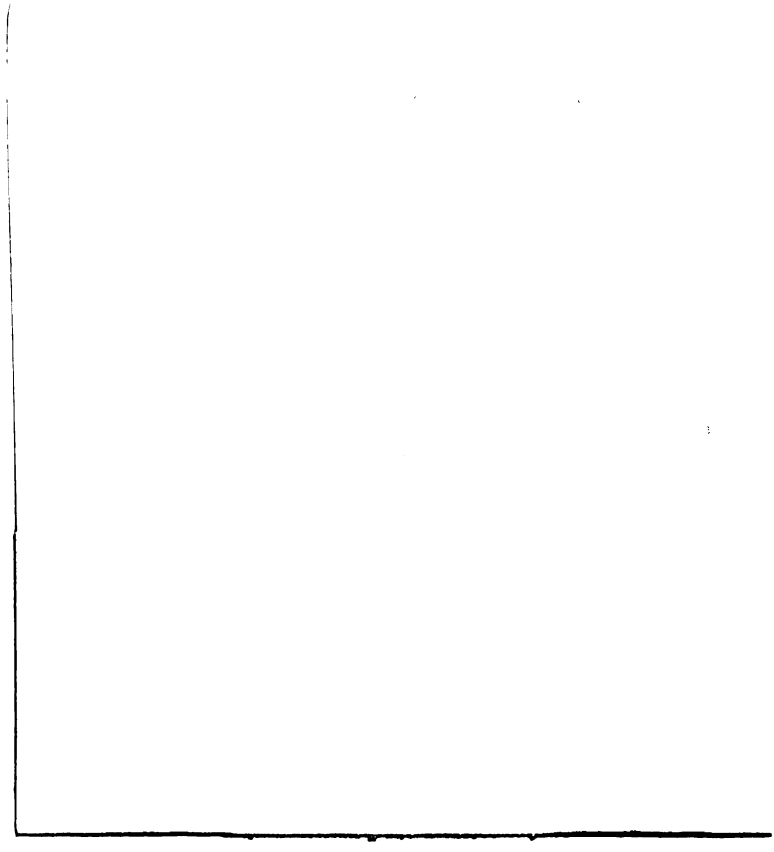

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